HOW TO PHOTOGRAPH MICROSCOPIC OBJECTS:

OR

LESSONS IN PHOTO-MICROGRAPHY FOR BEGINNERS.

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REPRINTED FROM THE "PHOTOGRAPHIC NEWS,"
With many Additions.

AND A CHAPTER ON PREPARING BACTERIA,
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Dedication.

TO

R. L. MADDOX, ESQ., M.D., HON. F.R.M.S., ETC.

TO WHOM THE AUTHOR IS INDEBTED FOR THE CHAPTER ON "PREPARING AND PHOTOGRAPHING BACTERIA," IN WHOSE STEPS HE HAS BEEN A HUMBLE FOLLOWER, AND BY WHOSE TEACHINGS HE HAS LARGELY PROFITED,

THIS LITTLE BOOK IS BY PERMISSION

DEDICATED.

PREFACE.

THE *raison d'être* of this little book is as follows. During the time that the writer has practised photography as a help in his microscopical studies, he has frequently met with microscopists who, recognizing the great value of photography as a means of making a truthful record of their work, desired to commence the art, but were deterred from so doing, either by supposed difficulties, or by the want of books treating specially on this branch of photography. The writer has repeatedly been asked to read papers, or to give some information, on photo-micrography, and he has found a general complaint that there is no elementary work on the subject published in this country. This want of simple, elementary information, he himself experienced when commencing photo-micrography. The more advanced student, however, will find many excellent papers in the pages of the *Monthly Microscopical Journal*, *The Transactions of the Royal Microscopical Society*, and will learn much from the chapter on photo-micrography in Dr. Beale's book, "How to Work with the Microscope."

It was to meet this want that the following pages have been written, and the writer wishes to point out that, while he had specially in view the needs of the experienced microscopist who wished to obtain a knowledge of microscopical photography, he did not forget the claims of those who, knowing little or nothing either of microscopy or photography, wished to begin

the practice of both. It was with this object in view that so much space has been given to the subject of lenses and microscopical apparatus generally, for on no subject does the young microscopist so much need sound advice; without it he is apt to have palmed off on him, frequently at an exorbitant price, some gaily-lacquered microscope, which appears to his inexperience at first absolute perfection, but which a little practice soon proves utterly worthless. There are so many wretched specimens of workmanship in the market, sold as microscopes, by persons who are opticians only in name, that it is necessary to caution all beginners who want a microscope for *real work*, against purchasing an instrument from any but an optician of reputation. All cheap microscopes are not necessarily bad, while many bad microscopes are very high-priced. All the best English makers now produce microscopes of high excellence, at a very low price, which are fitted for doing all ordinary work, being of sound, exact workmanship, convenient in design, and furnished with really good lenses. Several of these instruments are figured and described in the following pages; but it must be understood that there are also other London makers, not named, who produce similar instruments; but it has been the writer's aim, not only to mention good instruments, but such as appeared to him specially fitted for the practice of photo-micrography, and sold at a moderate price.

The largest instruments of Swift, Ross, Collins, Baker, Powell, and Beck, have neither been described nor recommended, simply because, perfect as these are in design and workmanship, their high price prevents their being possessed except by the few; while the smaller and moderate-priced instruments, such as Swift's new large model Wale's microscope, Collin's new model Harley, and Ross' Brewer's microscope, are equal to performing scientific work of the highest and most delicate description, and are fitted with every convenience the

worker can possibly desire, and are fully equal in finish to the larger stands. In fact, in such instruments, the student has, at a price that most can afford, greater perfection of workmanship, design, and finish, than could be obtained in the cumbrous forty or fifty guinea stands of thirty years ago. Nothing better can be desired by anyone, except for the mere purpose of show.

The smaller and simpler instruments described are specially suitable for the beginner, and are capable of withstanding a large amount of rough usage, and are equal to most of the work, photo-micrographic or otherwise, that will be required of them Such instruments will be found very useful, even to the microscopist who possesses more costly stands, as they are very useful for carrying about, and will save a valuable microscope from much wear and tear, such as is involved in using a microscope for photography.

In his remarks on lenses and apparatus generall , the writer has confined himself entirely to such as he has hi self worked with and tested in the actual practice of photo- icrography. This will explain why many, doubtless useful, pi. ecs of apparatus are not noticed.

Several novelties are figured and described, which are calculated to prove very useful to the photo-micrographer. Amongst these may be mentioned Swift's Gas microscope, and his new photo-micrographic apparatus. A few improved forms of apparatus are noted, such as Swift's very ingenious Popular condenser, his various sizes and patterns of the Wale's microscope, and Collins' new form of the very useful Webster condenser. From a practical trial of all these, the writer can confidently affirm that the student who requires a good microscope or accessories, cannot go wrong in choosing from any that he has mentioned.

In his practical directions for development of negatives, printing, &c., the writer has tried to be as plain as possible,

and has mentioned the simplest, and at times apparently trivial, details, that he might avoid omitting anything that could be of the slightest possible help to the beginner, who, when first venturing upon the mysteries of development, printing, toning, &c., is apt to feel bewildered by the number of new and strange operations he has to perform. It is hoped that the chapter treating on defects in photo-micrographic negatives and their remedies will prove one of the most useful to the beginner.

For further information on photographic matters, the student is referred to Captain Abney's "Instruction in Photography," Burton's "Modern Photography," and other valuable books published by Messrs. Piper and Carter. The whole series of these "Handy-Books" will form a most complete reference library for the photo-micrographer. For instruction in microscopical details, Carpenter's "Microscope and its Revelations," and Davis's "Practical Microscopy," will be found by far the most useful text-books on general microscopy; while the works of Dr. Beale may be consulted by the more advanced student for special information. The "Micrographic Dictionary" may be referred to at times with advantage; but the book, as a whole, does not satisfy the requirements of the microscopical student. Dr. Sternberg's "Photo-Micrographs and How to Make Them," is a most excellent introduction to the study of biology, but contains very little instruction in photography or microscopy.

In conclusion, the writer wishes to thank those opticians who so kindly and readily gave him information, or lent him apparatus or illustrations. His thanks are also due to the Publishers for the great interest they have taken in this little book, and for their kindness in carrying out his wishes.

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HOW TO PHOTOGRAPH MICROSCOPIC OBJECTS.

INTRODUCTION.

Photo-micrography is the art of making, by means of the microscope, photographic enlargements of microscopic objects. Properly employed it forms a valuable tool in the apparatus of the scientific worker, for, by its aid, he can record faithfully the results of difficult and delicate operations, or delineate the forms of minute bodies, concerning whose true structure different observers may vary in opinion. A photo-micrograph allows no room for play of the imagination: it simply shows how a given object appeared at the time the observation was made. Seriously carried out, and more especially when using high powers, photo-micrography is hard and trying work. The arrangement of the apparatus, the placing and illumination of the object, are tedious and difficult. Beginners in this fascinating and important art are warned that they must be prepared to encounter not only all the difficulties and troubles incident to ordinary photography, but also others of a different nature peculiar to photo-micrography.

To become a skilful photo-micrographer it is first necessary to be a skilful microscopist; for if the operator does not know

how to display an object to the best advantage, his photographs will be useless. Yet the microscopist who comes fresh to photographic operations will find himself in a sea of troubles, spoil a number of plates, produce failure after failure, and, perhaps, throw up photo-micrography in disgust. The writer would advise all who contemplate a beginning to first make themselves acquainted with landscape photography, and all ordinary photographic manipulation: this need involve little extra expense, and the profit and pleasure to be gained from this course will amply repay any little additional outlay. One of the most skilful photo-micrographers that the writer ever knew was a gentleman who employed the microscope regularly as an instrument of research, but who used the camera only on his holiday trips. Being engaged in writing a paper which required illustration, it occurred to him to try photo-micrography, as the objects which he wished to depict were beyond the skill of the engraver. He did so, and succeeded at once.

Beginners in photo-micrography should bear in mind:—1st. That they should themselves develop every plate they expose; 2nd. That the best results need not be expected unless they are also able to make their own silver prints. A professional photographer may be A1 at landscape and portrait work, but this does not show that he is fit to be entrusted with negatives of microscopic objects. To bring out the details of a photo-micrographic negative of a print properly, requires that the operator should thoroughly understand the nature of the object; and this cannot be done except by a microscopist.

All objects are not suited for photo-micrography. Very opaque ones are not the worst, but those which have any strong tint of red, brown, or yellow. On this account many beautiful insect preparations cannot be photographed successfully; and we would, therefore, advise the beginner to study the preparation of microscopic objects, so as to be able, in case of need, to prepare and mount his own objects. As an example, a fly's

tongue forms a pretty microscopic object, and most of the slides met with are tolerably good; yet a photograph taken from these ordinary slides usually is a complete failure. The reason is, that the unequal transparency of the object makes some parts over-exposed, while, in the darker parts, the detail has not impressed the film. Here, the best way is to make, or have made, a special preparation.

Photo-micrography has had many followers amongst the scientific men of England, the continent of Europe and America, ever since Archer's wet collodion process was introduced. To enumerate all the names of all those who have practised the art successfully would take more space than can be spared; thus our object in the following pages will be to mention those who have been, as it were, pioneers in photo-micrography.

Dr. J. W. Draper, of New York, was probably the first to take a photo-micrograph. He was also the first to use the Daguerreotype process for taking portraits, having his sister to sit for him, in full sunlight, with her face powdered, and giving an exposure of twenty or thirty minutes. For the purpose of portraiture, the Daguerreotype process, as then practised, was necessarily unsatisfactory, as it was impossible for the sitter to keep still through such long exposures, and blurred and hazy outlines were all that could be obtained. However, lengthy exposures were no objection in the case of photographs of microscopic objects, and here Dr. Draper was very successful, for it is said that some of his earliest photo-micrographs, which are still in existence, taken on silvered plates, are marvels of beauty.

America has produced several very skilful photo-micrographers, foremost amongst whom may be mentioned Dr. Woodward, Dr. Draper, and Dr. Sternberg. The former has attained world-wide celebrity through his marvellous photographs of Nobert's test plates, and of the most difficult test-diatoms, such as *Amphipleura pellucida;* perhaps his work in this direction has never been equalled by anyone—certainly, never excelled.

Dr. Woodward, while executing these *feats* in photo-micrography, did not neglect the useful applications of the art, but was constantly employing his camera to illustrate various branches of physiology and pathology. To those who would wish to decry the use of expensive apparatus, we would say, that Dr. Woodward employed in his practice of photo-micrography none but the *very best* lenses and other apparatus, with which the Army Museum at Washington, thanks to the liberality and good sense of the American Government, was well supplied; and it is more than doubtful whether even Dr. Woodward's inimitable skill could have gained such grand results by the use of anything inferior. The worker whose means are limited may rest assured that although results of value can be obtained from the use of cheap apparatus, combined with intelligence and skill in their use, yet the highest departments of photo-micrography are only open to those who can add to patient skill and years of scientific experience, the possession of the best instruments that our opticians can produce.

Dr. Sternberg is best known to the scientific world through his work in connection with the Bacteria and other lowly organisms which are now proved to be the cause of many infectious diseases. For the purpose of recording his results, he has for many years made large use of photography, and has produced work of the very highest class. In 1880 he published a translation of Dr. Magnin's "The Bacteria," and illustrated it by heliotypes from his photographs. Last year he brought out a work entitled "Photo-Micrographs and how to make them," a thoroughly good book in every respect, but which perhaps possesses more value as a most delightful introduction to modern biology, than as a text-book on photo-micrography. It is illustrated by forty-seven photographs reproduced in heliotype, all of which possess great excellence.

In England the name of Dr. Maddox will be well-known to every photo-micrographer, for during the past thirty years he

has done more photo-micrographic work, and laboured more to bring the claims of the art before the scientific world, than any other man. As the inventor of gelatino-bromide plates, strange to say, his name is not so generally known—at least, in this country—for the great authorities on modern photography on the Continent (Dr. Eder and Dr. Vogel) have given due honour to Dr. Maddox for his invention. In England, the writer thinks, Dr. Maddox has never received sufficient recognition for an invention of such value—an invention which has revolutionised the whole science and practice of photography.

The photo-micrographs of Dr. Maddox are well known: perhaps among the best are his photograph of part of the frustule of *P. angulatum* x 3,000, his photographs of various *Coscinodisci* and other diatoms. A large series of slides for the lantern was made from Dr. Maddox's negatives, and this series had a world-wide fame. Dr. Maddox still continues the practice of photo-micrography, and his photographs of bacteria, illustrating papers which he has recently contributed to the Royal Microscopical Society, have been pronounced by competent authorities to be unsurpassed even by the splendid productions of Koch.

Mr. Wenham, so well known as the inventor of the binocular prism in general use, was at one time a very energetic and successful photo-micrographer. Amongst others, the names of Mr. Shadbolt, Mr. G. E. Davis, Dr. Abercrombie, Dr. Wilson, and Dr. Redmayne, may be mentioned. Drs. Abercrombie and Wilson were co-workers, and gained considerable reputation by their photographs of diatoms, which were produced on wet plates. The light used was chiefly that from burning magnesium ribbon. The chief characteristics of the photo-micrographs produced by these gentlemen appear to have been great softness and delicacy of detail. They proved conclusively by their results what had before been doubted by many, that good work could be produced without a costly heliostat, by artificial light, and in fact without any expensive apparatus beyond a good microscope and first-class

lenses; for Drs. Abercrombie and Wilson, although working without the eyepiece, used only an ordinary short camera, which was connected with the microscope by means of a long cone of black calico, supported by rods running from the microscope tube to the body of the camera.

The names of many other English workers must be passed over, as it is not our intention to write a history of photo-micrography, but merely to pass in review the names of the earlier and more important photo-micrographers. Suffice it to say, that there have been many accomplished photo-micrographers in the past in this country who have had the courage to master all the difficulties, and the patience to bear with all the trials, incident to the wet plate process, who have produced work of the very highest order; and that at the present day, thanks to the merits of gelatino-bromide, the number of English photo-micrographers is steadily increasing from day to day, and although the many will perhaps take up the art merely as a pastime, doubtless there will not be wanting patient and steady workers who will practise photo-micrography simply for the advancement of science and the increase of the sum of human knowledge, and who will find in so doing far deeper and more lasting happiness, than in the desultory pourtraying of now a fly's leg, then a section of tobacco, next a young oyster, simply for the amusement of themselves and their friends.

On the Continent it would appear that photo-micrography has been more highly valued as a scientific tool than among ourselves. The scientific men of France and Germany are less conservative than our own, and are more ready to take advantage of any new process that may be made subservient to the cause of science. Hence, photo-micrography was at once recognized as a most valuable auxiliary in scientific work; the chemist, the botanist, the biologist, the physician, and the petrologist, were alike glad to avail themselves of its services in illustrating their special work, and thus Germany and France can boast of scientific works of

the highest value, illustrated by photographs from actual specimens—works which England has failed yet to produce. Witness, for example, the magnificent work of Cohen, "Collection of Photo-Micrographs of Minerals and Rocks," Barry's "Photo-Micrographs of Botanical Preparations," Reinsch's "Photo-Micrographs of the Structure of Coal," and Dr. Koch's unequalled works on Bacteria and other minute organisms which are connected with infectious deseases, all of which are profusely illustrated by photographs from actual specimens. In France, at the present time, Dr. Miquel, of the Observatory of Montsouris, is largely using photo-micrography to record the results of his studies of the lower organisms, which are of the highest interest and importance. Many other French scientific workers are also at the present day making use of photo-micrography to aid them in researches where, owing to the minuteness of the objects to be depicted, the skill of the engraver utterly fails. It cannot be doubted that, as time goes on, the value of photo-micrography will be better estimated, and that wherever truth is wanted, the sometimes rough rendering of the camera will be far more highly prized than the most exquisitely finished picture the engraver's tool can produce.

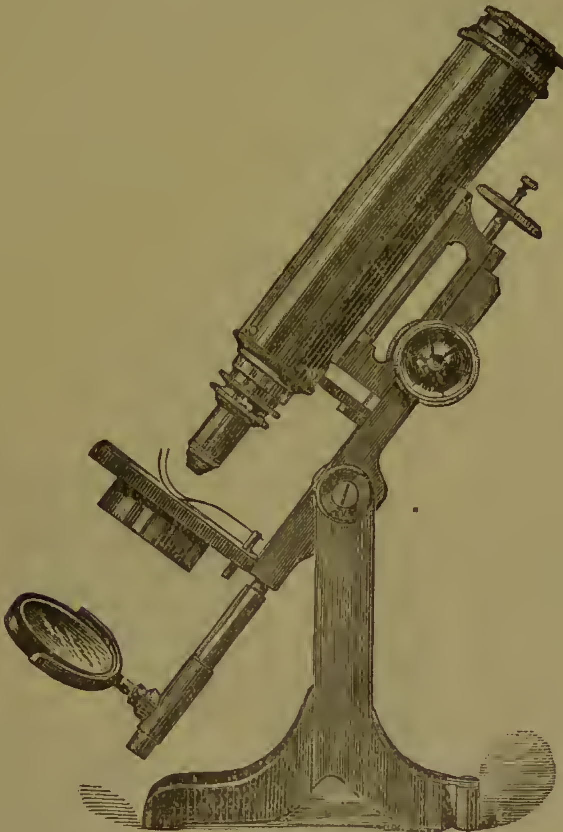
CHAPTER I.

MICROSCOPICAL APPARATUS.

Any good microscope stand may be employed for photo-micrography. It must be really good; an inferior instrument is useless. It must be firmly and solidly built, and the fine and coarse adjustments should be of the best construction. One of the cheap microscopes, with a fine adjustment that gradually moves the object from the field of view on being turned, will be found a source of continual annoyance, and should be avoided. If the student have, by ignorance or ill-advice, one of these things, let him part with it at any price, and procure one of the low-priced but firmly built, well-adjusted stands made by Beck, Collins, Ross, or Swift. These will be found to give ample satisfaction.

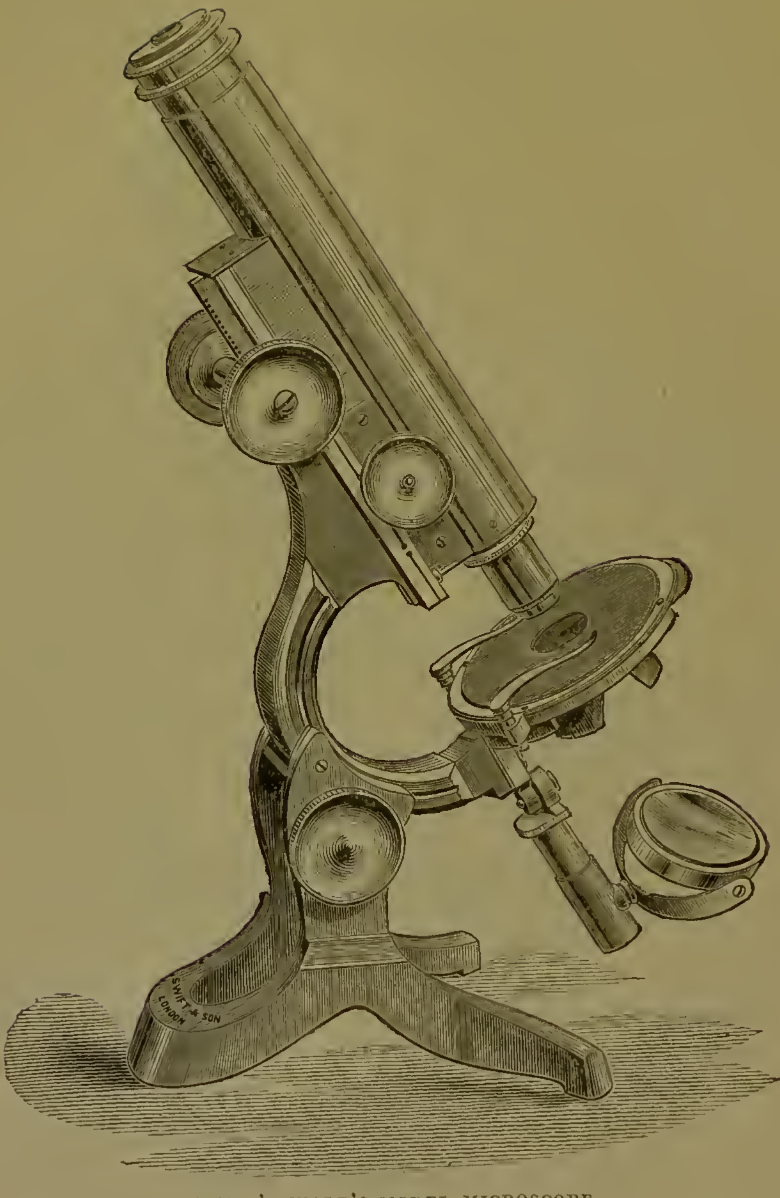
The stand figured on page 9, made by Mr. Collins, of Portland Street, is well suited to photo-micrographic work. It is well made, takes the full-sized eye-pieces, is furnished with a good one-inch and quarter-inch, and costs, with case, only £5 10s. A beginner could not have a better instrument. The writer uses a stand by Swift, which has a coarse adjustment so good, that a 1-12th or 1-16th inch may be focussed with ease and precision with it alone. The shape of the microscope is immaterial; both Ross and Jackson models will give good results if well made. A graduated draw-tube should be obtained, which had best be velvet-lined, to prevent flare. The usual dead black,

after a while, wears out of the draw-tube, and renders the microscope useless for photography; thus a more durable material, such as cloth or velvet, should be used to prevent reflection from the sides of the tube.



COLLINS' HISTOLOGICAL MICROSCOPE.

Another form of stand, a modification of one manufactured by Wale, of the United States, has lately been introduced by Mr. Swift. It is very firmly and solidly built, and has Mr. Swift's patent spiral rack-and-pinion focussing adjustment, which gives great smoothness and delicacy of motion; so much so, that the fine adjustment is not needed except for the very highest powers. The cut shows the mode by which the microscope is



SWIFT'S WALE'S-MODEL MICROSCOPE.

firmly clamped in any position. For real rough work, such as every microscope has to endure when used for photo-micrography, this microscope has no equal.

Even the experienced microscopist, who may possess one or more costly instruments, will find it an advantage to purchase a strong useful stand such as this, and thus save the delicate adjustments and exquisite finish of his larger and more valuable stands.

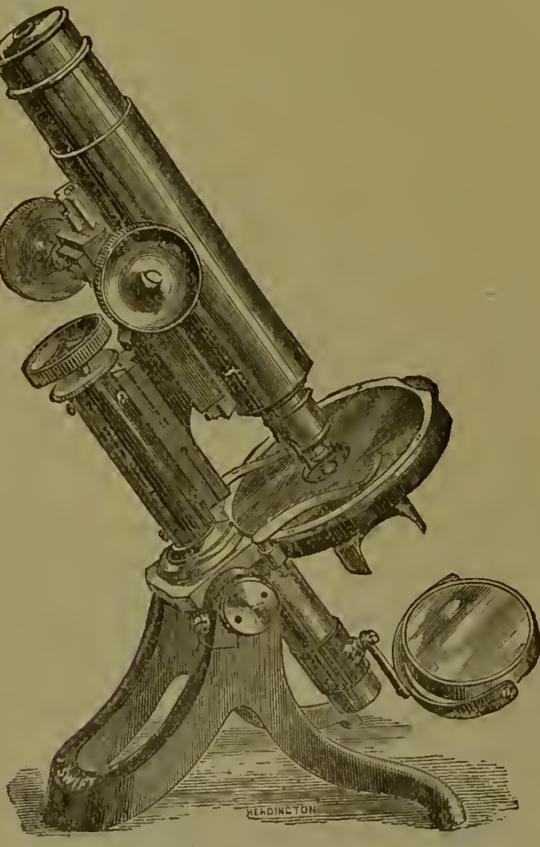
The price of this microscope, with cabinet and 1 inch and 1-5 inch objectives, is £8 8s., or without objectives, £6. A well-made stand such as this will last a lifetime, and give every satisfaction. The writer has had an extensive experience of the microscopes manufactured by Messrs. Swift, and has found exact and sound workmanship a characteristic of all, even in those of lowest price, while, in the more expensive stands the most exacting and fastidious microscopist could not desire greater perfection of appliance and finish.

The college microscope, also manufactured by Messrs. Swift, is a good instrument, well adapted to meet the wants of those who require a cheaper and simpler form of stand. It is manufactured specially for the use of medical students, but makes a very good microscope for photo-micrographic work. It is well balanced, and the focussing adjustments are both delicate in action and very strong.

The cut on p. 12 shows the more complete form of this instrument, the cheaper form costing, with case and two objectives, £5 5s., and the form with rack and revolving stage, £6 15s.

Other moderate-priced instruments, suited to the purposes of the photo-micrographer, are manufactured by Messrs. Ross, Baker, and Beck, but the writer wishes to mention particularly *only* such microscopes as he has personally examined or worked with; however, if the student purchases an instrument from any of the makers named, he cannot fail to get a really good instrument, capable of doing real, hard work, which will give the utmost

satisfaction; for the best English makers consider efficiency and durability before empty finish, and never turn out a bad microscope, no matter how low-priced.



SWIFT AND SON'S NEW COLLEGE MICROSCOPE.

Several of the Continental models, such as Hartnack's, would be useful for photo-micrography, from their compact shape and solidity; but their narrow body-tube, which limits the field of view most seriously, and cramped stage, render it advisable to use only English instruments of the latest pattern. If cost be no consideration, then there is nothing to equal one of the large, first-class microscopes of the best English makers, fitted with

every possible convenience in stage and sub-stage. It is true, an expert manipulator will obtain excellent results with the simplest arrangements; but it is no less true that it is the expert alone who can really appreciate and turn to good account the delicate mechanical contrivances which the skill of the optician has devised for his aid. Thus, a mechanical stage is not absolutely necessary, but it is a great help when working with high powers; and with the very highest powers, it is hard to see how it can be dispensed with. The same may be said of the sub-stage; but as this is in some respects more generally useful than the mechanical stage, it should be applied to all microscopes with which an achromatic condenser or paraboloid is to be used. The objections to the tube-fittings usually supplied with students' microscopes are, the difficulty of properly adjusting the sub-stage apparatus, and the very thick upper stage that they necessitate. For photographic work, the upper stage should be as thin as possible, certainly not more than one-eighth inch thick, for frequently very oblique light must be employed, and this cannot be done with a thick stage, which cuts off the rays. Using a thin stage and bull's-eye lens, it is astonishing how easily a difficult diatom may be resolved, which, with a thick stage, would require the use of an expensive condenser. Most of the English makers now fit their microscopes with thin concentric stages, even when rack-and-pinion movement is omitted.

If a large or medium-size microscope be employed, it should be furnished with the swinging sub-stage, by means of which the most delicate markings may be brought out with the simplest form of achromatic condenser; while dark-ground illumination may be obtained by the mirror alone, simply by swinging the sub-stage bar so far to one side, as to allow the rays from the mirror to pass through the object too obliquely to enter the object-glass. In all microscopes the mirror should be fixed by *two* crank arms to the tail-piece, to allow of sufficient freedom

of motion in using oblique light. If a sub-stage be used, there should be an adapter to enable the low-power objectives to be used as achromatic condensers, and with the swinging sub-stage they will be found most efficient.

As to lenses, the student is advised strongly to buy the very best, if possible. Let him shun cheap French lenses, more especially the separating lenses, styled "French buttons," which are frequently supplied with £5 or £6 microscopes, and which are only useless rubbish. The stand and lenses should be purchased separately; the latter to suit the requirements of the photo-micrographer. If the very best lenses are too expensive, then purchase some of the cheap low-angle lenses, now sold by most good makers, for these, being well corrected up to the angle ascribed to them, are capable of performing a vast amount of real work. The beginner will probably find them much easier to handle than lenses of wider aperture, owing to their greater penetration and working distance; but the more experienced worker will require, especially for photographing very minute objects, lenses of the widest possible angle. Lenses of wide-angle admit more light, and have far greater resolving power than lenses of low-angle; but they have less working distance, and less penetration. The fact that they almost touch the object in many cases, when in focus, forms no objection to their use for photography; but it is annoying to have a lens, say a half-inch, that will only show the surfaces of objects. This objection, however, can be easily disposed of by using a contracting diaphragm, such as the "Davis Aperture Shutter," made and sold by Mr. Collins, whenever penetration is desired. The use of this shutter renders a lens of widest angle equal to any low-angle lens, as far as penetration is concerned; while even with the shutter, the wide-angle lens will give superior definition, and admit more light than a low-angle lens of the same focus.

The writer has used with great success the low-angle lenses

introduced a few years ago by Messrs. Swift. They are low-priced—the 1-5th inch costing only £1 12s.—but are capable of doing really good work. The 1-5th inch will clearly show the striæ on a small *Pleurosigma angulatum*, with mirror and A eye-piece; yet, owing to its conical cell and long working-distance, can be easily used for exhibiting opaque objects. It is very useful for photography where great resolving power is not required. The half-inch, 1-6th inch, and 1-8th inch, also of low-angle, by the same makers, are very satisfactory lenses, as the writer can testify from actual use of them; for ordinary botanical, petrological, and histological work they are all that can be desired. However, as stated above, lenses of the very highest angle will be required by the experienced worker, for the very best results with difficult subjects can only be gained by using the very best instruments, and these are necessarily expensive. Still, there is no need to go to the French for cheap lenses, as lenses infinitely superior, such as those mentioned above, and at about the same price, can be obtained from most of our leading opticians. A few years ago no cheap lenses, except of foreign make, could be purchased, and Mr. Swift was perhaps the very first to introduce a series of low-angle lenses, which, while as cheap as the French ones, should be better corrected, and in better mounts. In this he has been followed by all our English makers.

The choice of lenses will depend, in a great measure, on the photographic work to be performed. If the beginner proposes to limit himself to the photography of comparatively easy objects, lenses of two-inch, one-inch, half-inch, and quarter-inch focus, will suffice. A quarter-inch of wide-angle will be found capable of resolving the majority of test-objects satisfactorily. A five-inch or four-inch will be found very useful for photographing large objects, such as whole insects, wood sections, and anatomical preparations; while if the student requires a few high powers, and cannot afford the expensive ones of the best English makers, he will find the moderate priced immersion lenses of Seibert

equal to all the work that will generally be required of them. These lenses are sold by Baker, of Holborn. Immersion lenses are specially useful in photography, as they admit a vast amount of light, and are, therefore, very rapid in action.

LEG OF WATER BOATMAN (NOTONECTA). Taken with a Ross' 4-inch.

The writer can recommend Siebert's lenses with the greatest confidence, as he has used several of them at different times, especially an immersion one-sixteenth inch, which gave him very great satisfaction. Not only does this lens give good results, but it is very easy to use, gives plenty of light, and has considerable "working distance," and will work well, even through a thick cover-glass. The one used by the writer has no collar-

adjustment, but gives a good sharp image of a diatom on the focussing screen, four feet to five feet away from the object. Many of the French fourths and eighths are so dark that it is difficult to focus with them; such lenses are most unfit for photography. A student not over rich might profitably set up a battery of lenses, of which the lower powers should be English, as these are not only of higher angle, but also are usually better mounted than the foreign low powers, and the higher powers, say from one eighth-inch upwards, lenses by Seibert, Zeiss, or Leitz. For one-twelfths and one-sixteenths upwards, or even from the one-eighth inch objective, immersion lenses should be chosen, as in photo-micrography they are easier to work with than dry lenses, and give far more light.

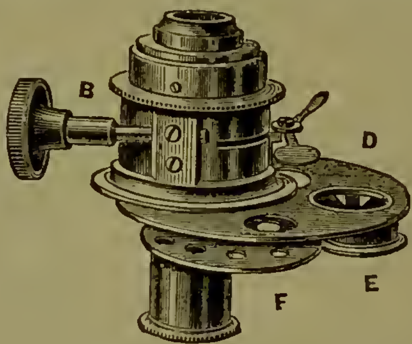
Some lenses are not well suited to photo-micrography, their visual and actinic foci not being coincident: that is, when an object is focussed accurately on the screen of the camera, and a photograph taken, the picture will be found indistinct and blurred, owing to the fact that the rays forming the visual image do not lie in the same plane as those forming the photographic image. Such lenses *may* be used for photography, by making experiments, and determining the amount of allowance for this difference to be made when focussing; but it is far more satisfactory to use lenses which do not require such correction. The writer has used lenses by Ross, Wale, Swift, and Seibert, and the visual and actinic foci were coincident in nearly all that he has used.*

Much difference of opinion prevails as to to whether the eye-piece should or should not be used in photo-micrography. Some assert that the eye-piece spoils good definition. This is possible with a bad eye-piece; but the writer has for years used the A eye-piece when photographing with low powers, and has found no

* Any lens may be *corrected* for special photographic use, by the addition of a supplementary lens. Cost of this addition about 10s.

difficulty in obtaining photographs absolutely sharp and well-defined to the very edge of the field. This is also the experience of many other photo-micrographers. In the writer's opinion it is a mere question of convenience: with low powers—say up to quarter inch—the eye-piece may be employed, as the loss of light attending its use is very slight; but with higher powers the loss becomes a serious matter, so it is then necessary to discard the eye-piece, or focussing will be very difficult, and the exposure of the plate inconveniently long.

An achromatic condenser is a very useful piece of apparatus, but may be dispensed with for general work; however, a good



one will save much labour and "dodging" when using high powers with difficult objects.

Except for the very highest powers and most delicate work, Swift's Popular achromatic condenser, figured above, will be found invaluable. It combines achromatic condenser (which works well up to a power of one-eighth inch), spot-lens, polariscope, diaphragm for test-stops, ordinary diaphragm, and selenite diaphragm for use with the polariscope. It has rack-and-pinion for focussing, and can be fitted to any good working microscope. From actual experience of its working, the writer can strongly recommend this piece of apparatus, and the photo-micrographer, after using it a short time, will be delighted with it; for the convenience and advantage of having all the ordinary adjuncts to

illumination always in place beneath the stage cannot be overestimated. When not required it can easily be removed. The price is four guineas. Messrs. Swift also make a superior condenser similar to the Popular, but more perfect in detail, which will suit the advanced worker, as it is capable of being used with the highest powers. For all ordinary work, however, the Popular will be found amply sufficient. Mr. Collins makes a good form of condenser, called the "Webster," which can also be used for dark ground illumination.

Messrs. Watson and Sons, of 313, High Holborn, manufacture a very good form of oil-immersion condenser for use with immersion lenses. It consists of a hemispherical lens mounted in ebonite, and when in use is placed beneath the object-slide. Through the kindness of Messrs. Watson, the writer has had an opportunity of severely testing this neat little piece of apparatus, which is of the greatest use in resolving troublesome diatoms. Of course, it requires practice to use it sufficiently, but when the student becomes accustomed to its manipulation, it is astonishing how it brings out the resolving powers of a lens. It will be found by the photo-micrographer to be most valuable in photographing diatoms, test scales, or any objects that require considerable obliquity of light. The same firm also make a safety stage, for use with high powers and valuable slides. The beginner will find it very useful in preventing injury to either object or lens when the latter approaches the object rather closely.

For modifying the light, which is sometimes so strong as to "drown" very transparent objects, Mr. Collins makes a very excellent light-modifier, which consists of a diaphragm, into the apertures of which are fitted blue glass discs of different shades, and a disc of finely-ground glass. The diaphragm is mounted on a stage-plate, which is placed beneath the object.

Photographing opaque objects is generally found to be very unsatisfactory work, from the difficulty of properly illuminating

the object, and the consequent long exposures required. For this work, the bull's-eye lens alone is not sufficient, but should be used in conjunction with the parabolic reflector. A very good form, manufactured by most opticians, is shown below. It is far superior to the old Ross' Silver Side Illuminator, which the photo-micrographer will find of very little use. The parabolic reflector gives a flood of light, and abolishes the heavy

PARABOLIC REFLECTOR.

shadows that so frequently render photographs of opaque objects of no value.

For very oblique light, the hemispherical lens and Wenham's disc will be found very useful. They may be obtained at a low

price, both mounted and unmounted, of Mr. Baker, 244, High Holborn. The hemispherical lens is perhaps most useful when mounted on a brass slip, but most workers find Wenham's disc give better results when merely attached to the object-slide with a mixture of glycerine and pure white gum.

The paraboloid and spot-lens are sometimes used in photo-micrography, but even with the most rapid dry plates, dark-

BULL'S-EYE LENS.

ground illumination is very difficult, and seldom really successful. However, many objects are best seen when thus lighted,

and most of the difficulties vanish when a good achromatic condenser is used. It is best to dispense with the eye-piece when photographing objects illuminated by the paraboloid.

The bull's-eye lens accompanies most microscopes, and is one of the most valuable accessories the microscopist possesses, when he has learnt how to use it properly. For photography, a small one is of little use; a large one, like that figured, should be obtained.

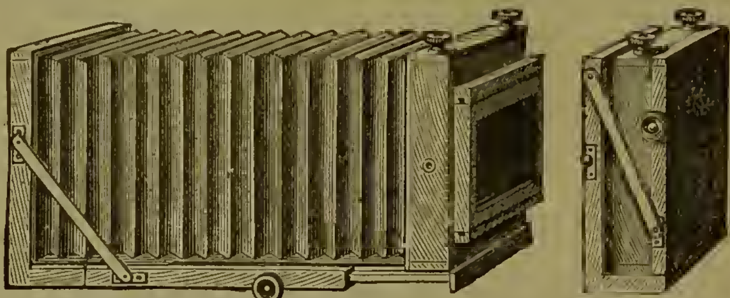
CHAPTER II.

PHOTOGRAPHIC APPARATUS.

For simple photo-micrographic operations, any ordinary camera may be employed. A quarter-plate camera will answer, but the student is advised to obtain a half-plate, or even a whole-plate camera, for, as he advances in skill, he will, perhaps, wish to photograph sections of rocks, or wood, or whole insects, on a larger scale than the smaller camera will allow. A good lens will make a half or whole-plate enlargement of an object without loss of definition. Using the eye-piece, and working with low powers, a camera expanding to eighteen inches or two feet will suffice, but for the higher powers, which cannot well be used in conjunction with the eye-piece, a camera expanding to four feet, or even six feet, is recommended. The eye-piece cuts off so much light when working with high-power lenses, that focussing becomes difficult, if not impossible; while without it, focussing with a one-twelfth inch or one-sixteenth inch is an easy matter even when a condenser is not employed.

If an ordinary camera be employed, there are none better than those sold under the name of "long focus" cameras. The half-plate size expands from three inches to eighteen inches or twenty inches, which is ample for low powers, especially when working

with the eye-piece. The subjoined illustration shows a capital "long focus" camera, introduced by Hare, which will answer both for landscape and microscopic work, and forms an excellent



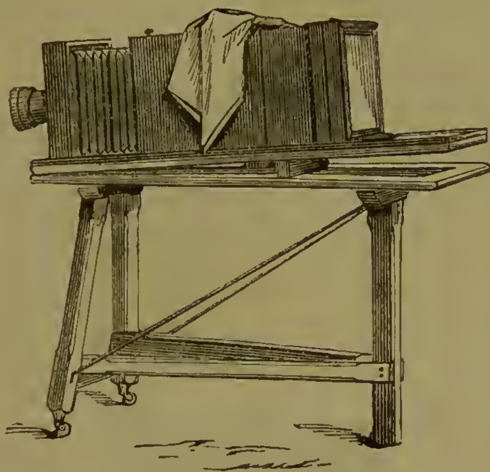
LONG FOCUS CAMERA, SUITABLE FOR PHOTO-MICROGRAPHY.

companion for the summer holidays, when the microscope will be, or ought to be, laid aside. Even the expert photo-micrographer will find the occasional practice of landscape photography a very good way of "keeping his hand in."

A long copying-camera, provided with focussing arrangements back and front, makes a very excellent camera for photo-micrography. It is very desirable that the front should not be fixed to the base-board, but be capable of either sliding back or moving back by screw, for frequently it may be necessary, after all is ready for taking a photograph, either to change the position of the object, or alter the illumination, which can be satisfactorily performed only by looking down the microscope tube. If the camera has to be removed for this purpose, there will be some difficulty in getting everything square again; while if the camera-front can slide back along the base-board, the relative position of microscope and screen remains unaltered. Copying-cameras suitable for photo-micrography are to be met with in the lists of most dealers in second-hand apparatus.

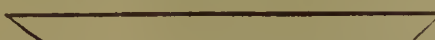
If the student cannot procure one of these cameras, he may very easily construct one for himself. Procure four boards nicely planed, ¼-inch thick, some inches longer than the proposed

camera, and $\frac{1}{2}$-inch less in width than the bellows are required. Make a long box with the boards, fastening them together at the



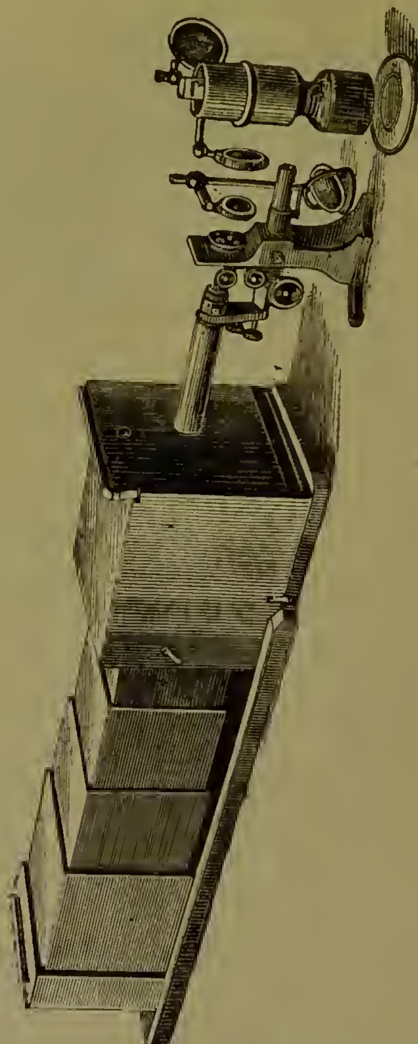
COPYING CAMERA.

ends only with screws. Cover this box with thin black calico or book-binder's cloth, pasting the edges together where they lap over. Next cut some slips of thin cardboard, $\frac{1}{2}$-inch or $\frac{3}{4}$-inch wide, and $\frac{1}{8}$-inch shorter than the width of the box. Cut the corners off each slip at an angle more acute than 45°, thus—



When sufficient have been cut, paste the slips exactly parallel on the four sides of the box, about $\frac{1}{8}$-inch or $\frac{3}{16}$-inch apart. Each slip must be pasted on with the cut-off ends facing in the same direction. When the paste is dry, put on an outer cover of better material; twilled calico will do, but is somewhat thick for the purpose; good book-binder's cloth is best. The edges should be pasted together as neatly as possible. When the whole is dry, unfasten the end screws, when the boards will collapse and the bellows can be drawn off. Now proceed to fold it up carefully, by pinching it into shape at the edges of the slips of cardboard, and put the bellows in a copying press, or under

heavy weights, for a day or two. The base-board for this bellows should extend in front about 3 feet, so that the microscope and lamp may stand upon it. As the bellows will require no pro-



tection, the camera-front may consist of a plain vertical board, of the right size, constructed to slide back on the base-board

about 15 or 18 inches. The dark slide should be purchased, preferably a single one, and the back of the camera made to fit it. The camera may be opened or closed by hand alone, the back moving in guides screwed along each side of the base-board; or by endless screw, cut with rather a coarse thread. When the endless screw is not used, a screw and butterfly-nut must be employed, to clamp the camera in any desired position.

If the student has not sufficient hand-skill to construct a bellows camera, he may make, or have made, the simpler arrangement represented above. As will be seen, it consists of a series of boxes, fitting into each other after the fashion of a sliding body camera. It can easily be lengthened or shortened by the addition or removal of one or more boxes. Any joiner could easily construct such a camera on seeing the illustration.

If the photo-micrographer desire specially to make slides for the lantern, he will find a little camera sold by the Sciopticon Company very convenient. It is made to take plates $3\frac{1}{4}$ in. by $3\frac{1}{4}$ in., and extends twelve inches. It is very light and compact, and costs, with four double slides, only £3 5s. For making lantern slides, either by copying, or from views in nature, or from microscopic objects, nothing could be more suitable. A large size to take $\frac{1}{4}$ plates is also made, and will suit those who prefer to have a margin on their lantern slides, either for the name, or for notes on the object. Plates $3\frac{1}{4}$ in. by $3\frac{1}{4}$ in. may now be had of any dealer in photographic apparatus.

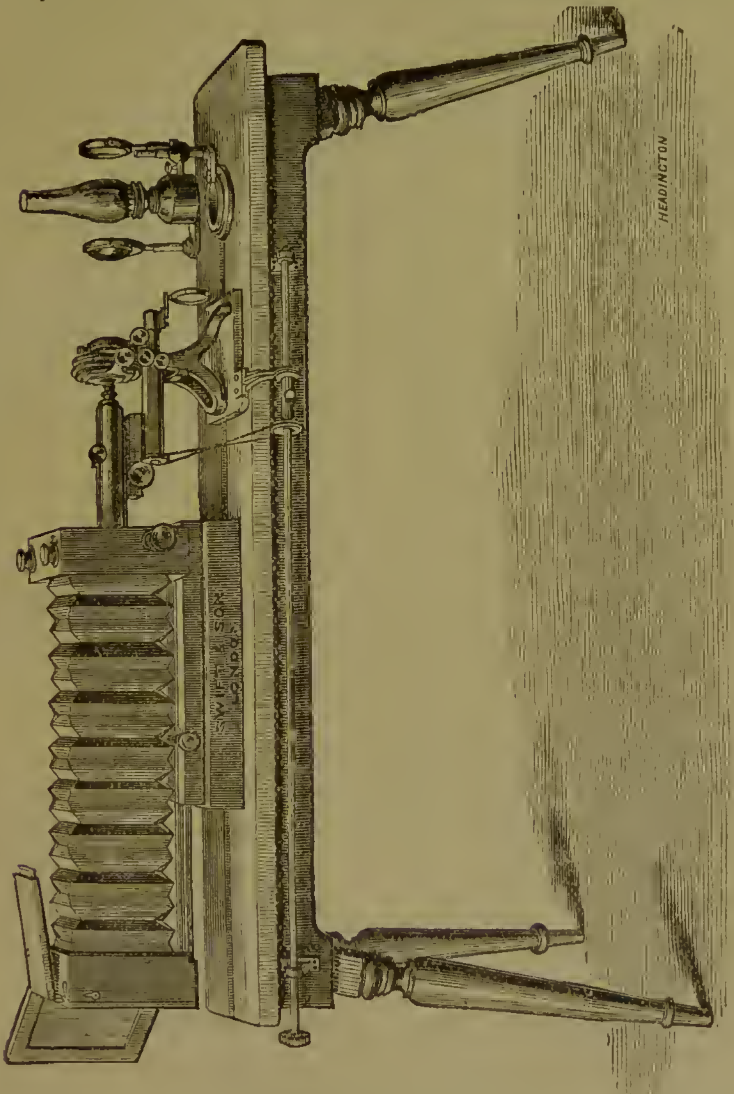
Double dark-slides may be employed, if well made, but a single slide is better, as the focussing-glass can be placed in it, and when replaced by the sensitive plate, the latter will lie in exactly the same plane, which is of vital importance. For low powers, very fine ground glass will answer, but for higher powers, plain glass is best. In this case the image must be examined by means of a focussing eye-piece. The following excellent mode of performing the difficult operation of focussing is given by Mr. G. E. Davis, in "Practical Microscopy:"—

"Removing the ground glass slide, another is substituted of mahogany, but pierced with a series of seven holes, into each of which the ordinary A eye-piece may be fixed. The thickness of the slide is such, that when the eye-piece is pushed in as far as it will go, the diaphragm lies in the same plane as the ground surface of the glass slide. To anyone accustomed to focus by the old method, the present system will be found a considerable improvement, it being easy under these conditions to obtain a sharp focus with an ordinary paraffin lamp when using the $\frac{1}{16}$-inch objective."

When the camera is extended only a short distance, the hand will be able to reach the coarse or fine adjustments of the microscope; but when drawn out to three feet or four feet, this will be impossible. It then becomes necessary to provide some method by which focussing can be easily and exactly performed while viewing the image on the screen, the camera being extended. Procure a hollow brass rod, $\frac{1}{2}$-inch in diameter, and the length of the base-board. Fix it to the side of the board by metal "eyes," so that the rod may revolve somewhat stiffly; if the camera be supported on trestles, the rod may be fixed under the base-board, which is more convenient. Make a grooved wooden wheel, two inches diameter, and fasten it to the rod, so that it will be opposite the fine adjustment of the microscope when the latter is placed horizontally, with the eye-piece end fitted to the camera-front. Make an endless band of narrow tape, of such a length that it will pass over the grooved wheel and the fine adjustment rather tightly. On turning the extremity of the rod, the fine adjustment will be moved with sufficient slowness and accuracy to allow of correct focussing with a lens of high power. The writer has long used an arrangement of this sort when photographing diatoms, and found it answer admirably.

A very excellent photo-micrographic camera has lately been introduced by Messrs Swift, and is figured below. As will be

seen, it is made on the general principles laid down above, but, as may be expected, the accuracy of workmanship and general



finish are only what may be expected in work produced by an experienced maker of scientific instruments, and far excel anything the most skilful amateur can hope to produce. Home-

made arrangements are often capable of turning out good work in the hands of a patient and skilful manipulator; but it is always best, when possible, to avail one's self of the experience and skill of the professional mechanic. The greater the perfection of the instruments, the greater will be the pleasure in using them, and therefore the probability of good results will be much increased. The attention of the photo-micrographer should be concentrated upon his special work, which will require all his care, and he thus can little afford to be distracted by the annoyance so frequently caused by imperfect apparatus.

The table upon which Swift's photo-micrographic apparatus is mounted is supported on three strong turned legs, which, for portability, are made to unscrew. The microscope is fixed upon a mahogany board which traverses the centre of the table by means of a slot, and can be fixed in any position, the camera being arranged in a similar way, which can be extended from twelve to thirty inches by double rack-work. The object can readily be focussed in any position of the microscope by the milled head at the end of the rod. The microscope has racked internal draw-tube for adjusting an amplifier when such is required.

The American photo-micrographers are accustomed to produce photo-micrographs of a much larger size than is usual amongst us. English workers appear rarely to attempt anything larger than quarter-plate size, or 5 inches by 4 inches; while the Americans frequently employ a power as high as $\frac{1}{8}$-inch to produce 10 in. by 8 in., or 12 in. by 10 in. pictures. Theory is here of little use: it is not a question of what ought to be done, but of what can be done. An enlargement from a small negative ought, theoretically, to be better than a large negative taken direct, but it very rarely is so; and the writer is inclined to agree with those American photo-micrographers who advocate the use of large plates with lenses of high angle—excepting, of course, where only lantern slides are required. The very best

photographs of rock-sections that the writer ever saw, were done on plates 8½ inches by 6½ inches, with powers varying from 2 inches to ⅛-inch.

In addition to the apparatus already mentioned, the following will be required:—A macintosh focussing-cloth; ebonite or glass dishes for developing and fixing negatives; glass measures, say, 2-oz., 4-oz., and 6-oz. capacity; basins for washing negatives; a porcelain dish for toning prints, and another for fixing them. Racks may be used for drying the negatives, but in winter, standing them up on a warm mantelpiece is as good a plan as any, unless the plates be made with very soft gelatine, when catastrophes may be expected in the shape of distortion of the image, or even melting of the gelatine.

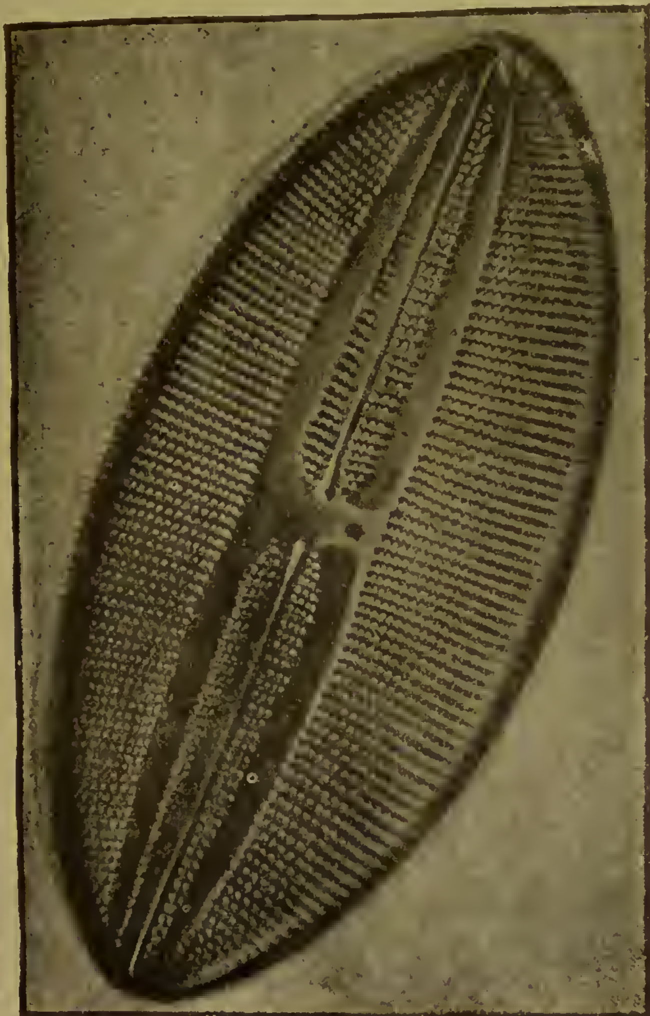
CHAPTER III.

ILLUMINATING APPARATUS.

In this country photo-micrography by daylight is troublesome and unsatisfactory. The sun shines brightly during so few months of the year, and is so fickle when he makes his appearance, that the photo-micrographer is compelled to fall back on artificial light to do his work. In many respects sunlight would be preferable, were it only always at the command of the photo-micrographer; it costs nothing, is rapid in its action, is more powerful than any other light, and exhibits objects illumined by it as we are accustomed to see them. The chief disadvantage of using the sun as a source of light is, that, owing to the earth's motion, the direction of the light is continually altering, necessitating the use of an expensive reflecting instrument, called a heliostat, to keep the rays constantly in any required direction.

The use of artificial light has been condemned by many. One photo-micrographer even goes so far as to say "artificial light is a delusion;" but on comparing results we shall find that, at least since the advent of rapid dry plates, photo-micrographs have been taken by many workers fully equal to any produced by daylight. In fact, certain photo-micrographers who have most strongly advocated the use of sunlight, have not produced work even equal to that which may be done by any manipulator of moderate ability with artificial light after a few months'

practice. Artificial light is much more easy to manage than daylight, and does not vary so much in actinic quality; hence



NAVICULA LYRA, × 900.
Taken with a Seibert's 1-16 immersion. Exposure about fifteen seconds to magnesium ribbon in a holder.

exposures are easy to calculate, and the illumination is more completely under control.

The light given by burning magnesium is the richest in actinic rays. If the student possesses a Solomon's magnesium lamp, he will find no difficulty in working with this light, the only objection to the lamp being that it consumes the magnesium rather rapidly, and thus becomes too expensive to be used constantly. It may, however, be used with great advantage when photographing very minute objects with high powers. The most economical mode of using magnesium ribbon is to burn it in a holder made of tin or brass tube, the bore being just large enough to admit the easy passage of the ribbon. The tube should be about six inches long, and mounted on a stand similar to that of the bull's-eye condenser, with joints to admit of proper adjustment.

When using the holder, a spirit lamp should be placed opposite the achromatic or other condenser, and the magnesium holder placed in such a position that when the ribbon is thrust through the tube, it may enter the flame of the spirit lamp. Some difficulty may be experienced in getting the ribbon to properly illuminate the screen, but a few experiments will render the matter easy. The writer has made considerable use of the above simple apparatus, and very satisfactorily; but as it necessitates two manipulators—one to attend to the light while focussing and arranging the correct position of the light, and another to superintend the screen and focus—he much prefers, for all purposes, a good paraffin lamp.

A well-made lamp is necessary, but good paraffin still more so. Avoid all low-priced, strong-smelling oils. Paraffin sold at 8d. per gallon is not only unfit for photo-micrography, but absolutely dangerous. When burnt in any lamp with a large wick, it begins to evaporate rapidly as the lamp gets warm, and after a while the flame will rush up the chimney, blackening it, perhaps cracking it, and frightening the operator, if doing nothing worse. Reliable paraffin may be had at 1s. 6d. per gallon, and this will give more satisfaction in every way. Duplex lamps may be

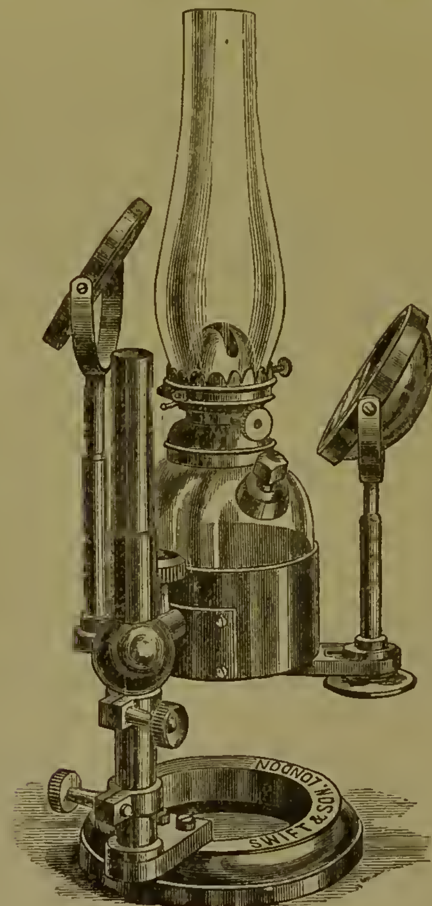
used, but they present no advantages for photo-micrography. They give out much heat, consume a large quantity of oil, and the double wick is troublesome when using high powers. A single wick is far preferable, but it should be the broadest possible to obtain.

The lamp devised by Mr. Dallinger specially for working with high powers is, perhaps, the very best yet made; but photographs can be taken with any paraffin lamp. For some time the writer used a tiny microscope lamp, and took some very successful photographs with lenses varying from 2 inches to 1-5th inch, but the exposure was necessarily long with all of them. The object of the photo-micrographer should be to make his exposures as short as possible, and this can only be done by using a powerful lamp and a vigorous developer.

The light from a broad-wick paraffin lamp will be found sufficient for even high-powers, but the brilliancy of the light may be much increased by putting a lump of camphor in the bowl of the lamp. Gaslight and candle-light are far too unsteady to be used for photo-micrography.

A very good lamp, well-suited to photo-micrography, and giving abundance of light, can be obtained at most lamp shops, or made to order at a small price. The wick should be 1½ inches or 2 inches wide, and the body of the lamp should be of metal, not glass nor china, as such lamps continually give annoyance through the burner becoming uncemented from the reservoir. When made of metal, the burner can be firmly soldered to the reservoir, and the chance of your lamp becoming useless just at the most important moment is avoided. The racks for turning up the wicks should be of good quality, for in cheap lamps the rack soon gets out of order, and becomes clogged in the wick, which can thus be neither turned up nor down. Good microscope lamps are made by Collins, Ross, Swift, and others, which will also answer for photo-micrography. The Fiddian lamp of Ross is a very excellent one, but somewhat troublesome to

keep in good working order; the "Bockett" lamp of Collins, the "Best microscope lamp" of Swift, and the new lamp of Parkes, of Birmingham, will all be found satisfactory. Swift's lamp is figured below; it is strongly made, and in many respects is the



most convenient and perfect lamp yet made for general use. It is fitted with porcelain shade.

The student who possesses a magic lantern or sciopticon will find it a very useful adjunct in photo-micrography, as the illumination is much more intense, and the heat much less, than

with ordinary lamps. Using one of these lanterns, the time of exposure is much lessened. Whatever lamp be used, great care should be taken to cut the wick level every time the lamp is required. For diffused light with low powers, the lamp should be used with the flame turned "broadside" to the lens; while with the high powers, where the greatest intensity of light is needed, the flame should be turned with its edge to the lens. Duplex lamps answer fairly well when photographing with low powers, but with powers from $\frac{1}{4}$-inch upwards it is very difficult to get satisfactory illumination, as there is a shadow from the two flames.

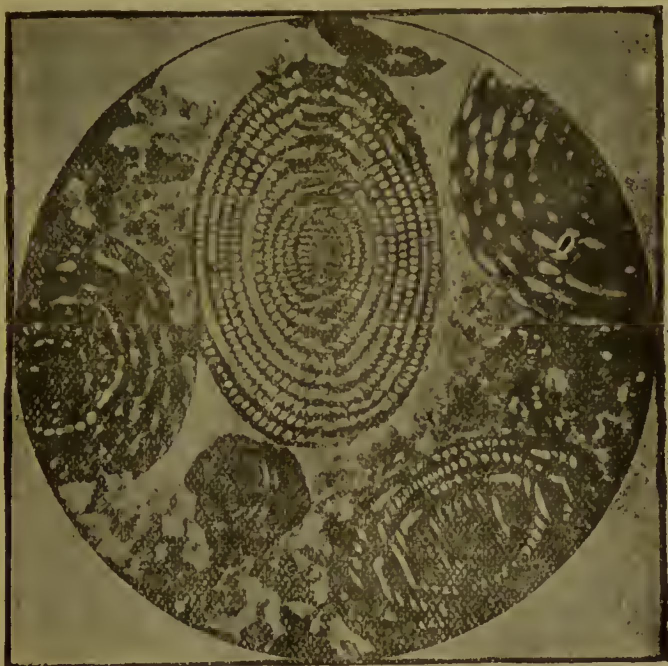
CHAPTER IV.

EXPOSING THE PLATE.

No rule can be laid down as to the duration of the exposure. It depends (1st) on the focal length of the lens used; (2nd) its aperture, wide-angle lenses being far quicker than those of low-angle; (3rd) the nature of the light used; (4th) the nature of the object, yellow and brown objects always requiring a prolonged exposure; (5th) the development. An operator who uses a weak developer will always expose his plates for an unnecessarily long time. The beginner will perhaps think the exposure the most difficult part of photo-micrography, but as he progresses he will alter his mind, and think the proper illumination of the object far more difficult.

Using a good paraffin lamp, and lenses of from 5 inches to one-sixteenth inch, exposures may vary from a fraction of a second to half an-hour. For instance, the larva of a flea, a very transparent object when properly illuminated, will not require more than half a second with the two-inch objective; while with the same lens, a section of coal may require twenty minutes. The section of Alveolina limestone figured below, although of a white colour, and apparently very transparent, had an exposure of fifteen minutes. As a rule, all rock sections will require a rather long exposure, as they stop a large amount of light. All sections should be as thin as possible; yet a good colour is of

more importance than thinness. The writer has a section of a tertiary limestone from Bengal, of a strong yellow colour, which he has often vainly tried to photograph satisfactorily, although the section is most admirably cut, and very thin.



SECTION OF ALVEOLINA LIMESTONE, HERAULT, BELGIUM.

In photographing rock sections, polarized light will frequently be required to bring out the structure properly. There are many rock sections which show little or no detail when viewed by ordinary light, yet which are seen to be of very complex structure when polarized light is used. Again, in petrology the polariscope is a most valuable help in assisting the student to analyse the constituents of a rock, or distinguish between different minerals. Thus in photographing sections of rocks, polarized light must often be employed. Unless the photo-micrographer can use a powerful achromatic condenser with the polariscope,

arranged as in Swift's "Popular Condenser," he will find that polarized light necessitates a very long exposure. It will require considerable experience to use the polariscope successfully in photography, for the arrangement of prisms that gives the best effect on the screen does not always give the best results on

WING OF MIDGE (PSYCHODA).

the negative. For example, the novice will be annoyed to find his brilliant blues come out *white* in the finished photograph, while reds, pinks, &c., are translated into different shades of

black. Perhaps it may be best, as a rule, to use only the more "non-actinic" tints in photographing with the polariscope.

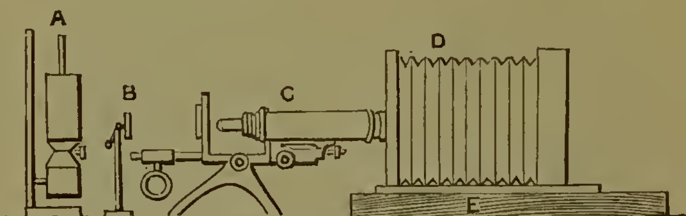
The wing of a midge, here shown, will serve as a good example of a very transparent object, which yet has plenty of detail. This object had an exposure of one second: less would have sufficed with a more powerful lamp.

High powers, being used chiefly with very transparent objects, do not require the tremendous exposures that people generally imagine. A one-sixteenth inch, when properly illuminated, will give a good clear image on the focussing screen five feet away from the object. When the writer first began using high powers, he heard such exaggerated statements about the difficulty attending their use, and the long exposures they required, that on first trying *P. angulatum*, he gave an exposure of an hour to this transparent object. On developing, the plate came out almost clear glass; only a faint ghost of the object could be seen on the plate. A subsequent exposure of fifteen minutes, under the same conditions, gave a fair negative. All objects are not fitted for photography, therefore it may be taken as a rule that if any object bears an exposure of half-an-hour with any lens, without being fully exposed, it is simply useless to attempt it. There is a little scarlet mite common in gardens, the scarlet *Trombidium*, which, owing to its colour, may be exposed for almost any period without getting any better photograph than a blank outline. Such objects should, if possible, be bleached before attempting to photograph them.

When magnesium ribbon is used as the source of light, the exposures become very rapid. The writer has never used this light with low powers, but he has found ten seconds to fifteen seconds ample for diatoms with the one-sixteenth inch objective.

The dry plates recommended for photo-micrography are the most rapid in the market. The writer has used Swan's ten times collodion, and thirty times collodion; and while the ten times are excellent for low powers, he still prefers the thirty

times plate for every purpose. He has also used plates still more rapid, and found them satisfactory in every way. Very rapid plates are often difficult to manipulate when used for landscape work, but when used for photo-micrography they become as easy to develop as any slow plate, while they have the great advantage of increased rapidity. The writer is not alone in advising the use of rapid plates, for the author of "Practical Microscopy" has obtained good results on Swan's fifteen times plate, while Dr. Sternberg, one of the most experienced and accomplished of living photo-micrographers, uses Eastman's instantaneous dry plates. The maker of the plates is of little importance. The writer has tried most of the makes in the market, and has got good results with all. The chief thing is that the plates be made of good hard gelatine. If a sample of plate be found to be prepared with soft gelatine, reject it at once. Frilling may be laughed at, but shrinkage of the film is simply ruin to all good work.

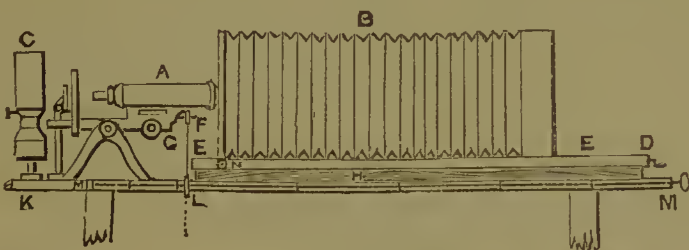


ARRANGEMENT OF MICROSCOPE WITH SHORT CAMERA FOR USE WITH EYE-PIECE.

A, lamp; B, condenser; C, microscope; D, short camera; E, block to support camera.

We come now to the actual exposure of the plate in the camera. First place the object on the stage of the microscope, choose your lens, and bring the object into focus. Notice carefully the chief points that you wish to be shown clearly in the photograph, that special attention may be paid to them in focussing and exposing. Then lay the microscope in the horizontal position, place the lamp in front, and adjust the illuminating apparatus in the best

position. The object may be seen best with oblique light; in this case be very careful, or the plate may not be fully illuminated, when the negative would be rendered worthless. When the illumination has been satisfactorily adjusted, draw the front of the camera up until the eye-piece of the microscope fits in the hole made for its reception. A hood of black velvet will probably be necessary to render the connection of camera and microscope light-tight. This done, view the object on the screen, which will be very indistinct. If the adjustments of the microscope are within reach, by their means slightly withdraw the lens from the object until the latter is in good focus. If the eye-piece be removed, and the adjustments are, therefore, out of reach, by reason of the length of the camera, turn the focussing rod until a satisfactory focus be obtained. When this is accomplished, leave the apparatus for a few minutes to allow of its



ARRANGEMENT OF MICROSCOPE WITH LONG CAMERA WHEN THE EYE-PIECE IS NOT USED.

A, microscope; B, camera; C, lamp; D, winch screw; E, base-board; F, fine adjustment; G, band connecting F with wheel of rod, L; H, block supporting camera; K, table; L, wheel of focussing rod; M, focussing rod; N, rack-and-pinion for moving camera front.

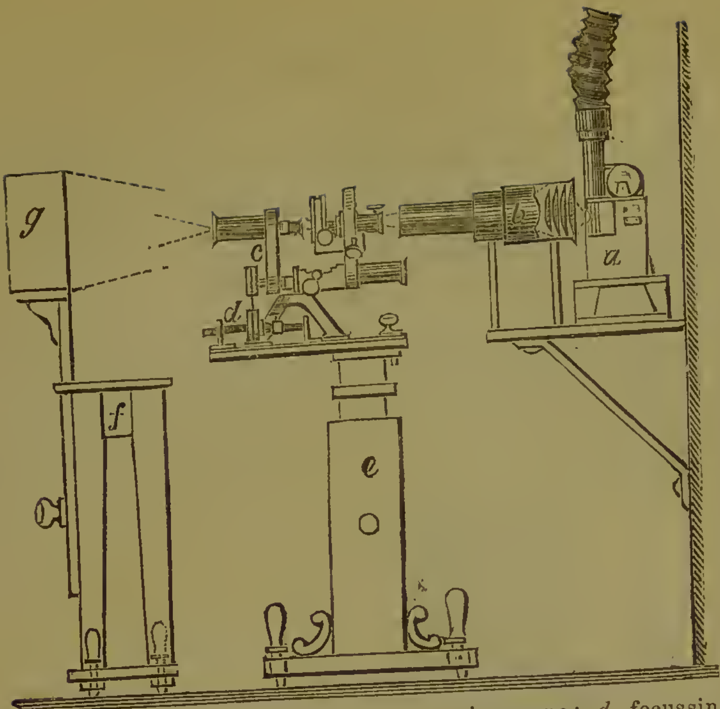
expansion from the heat of the lamp. With low powers, this expansion is hardly likely to affect the results, but with high powers is very injurious.

Sometimes, in fact, when using a high power, the expansion of the metal parts of the apparatus during a long exposure may be so great as to throw the object quite out of focus. It is thus advisable to place the lamp as far away from the microscope as

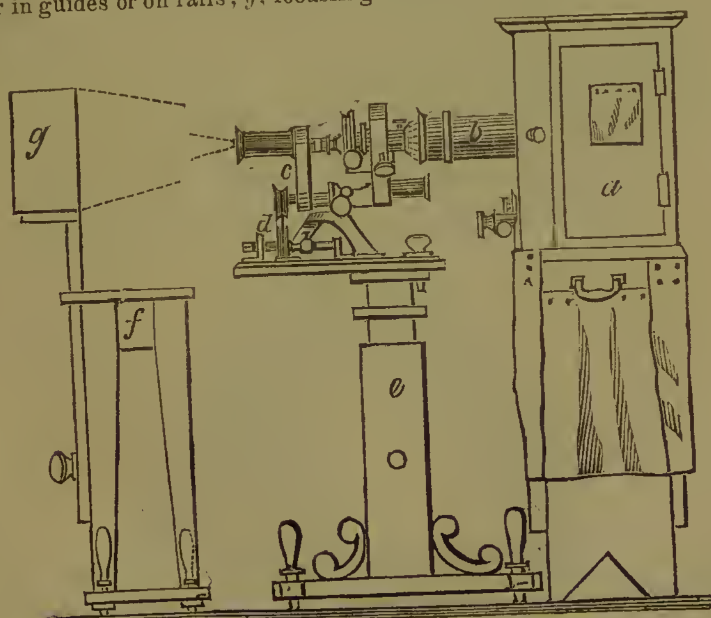
possible, consistent with suitable illumination. The writer frequently uses a card-board screen between the lamp and microscope, with an aperture to allow the rays to pass through. By this means the microscope is kept cool, and possible injury to the lens averted. The alum cell, used with the heliostat to stop the heat rays, can hardly be used successfully with lamp-light. Sometimes, however, a thin cell, containing ammonio-sulphate of copper, may be employed when photographing very transparent diatoms, and answers the double object of keeping off the heat from the lamp, and giving a more diffused light. For the latter purpose, with low powers only, a strip of fine ground glass or oiled paper may be placed beneath the object. A slide of blue glass, 3 inches by 1 inch, is also used by some operators for softening the light.

All being ready for an exposure, a blackened card must be placed opposite the lens, or below the stage, to cut off the light. With a low power, the card should be in front of the lens. The dark slide may then be inserted, and the shutter drawn up. After waiting for a few moments to allow all vibration to cease, the card in front of the lens must be rapidly removed. During the exposure, the operator must abstain from walking about the room, for the vibration so produced would injure the sharpness of the picture, more especially with low powers and short exposures. When the exposure is deemed sufficient, the blackened card must be replaced in front of the lens, and the shutter pushed down. If other exposures are to be given, do not turn the lamp down, but leave the flame the full height, until the next plate can be inserted in the camera. In this way the alternate expansion and contraction of the microscope, &c., is avoided. If, on developing, the first negative be found either over- or under-exposed, try again, without disturbing the apparatus.

The two following figures illustrate the method adopted by some workers of using the microscope in a dark room, and thus dispensing with a camera. If the student have sufficient room



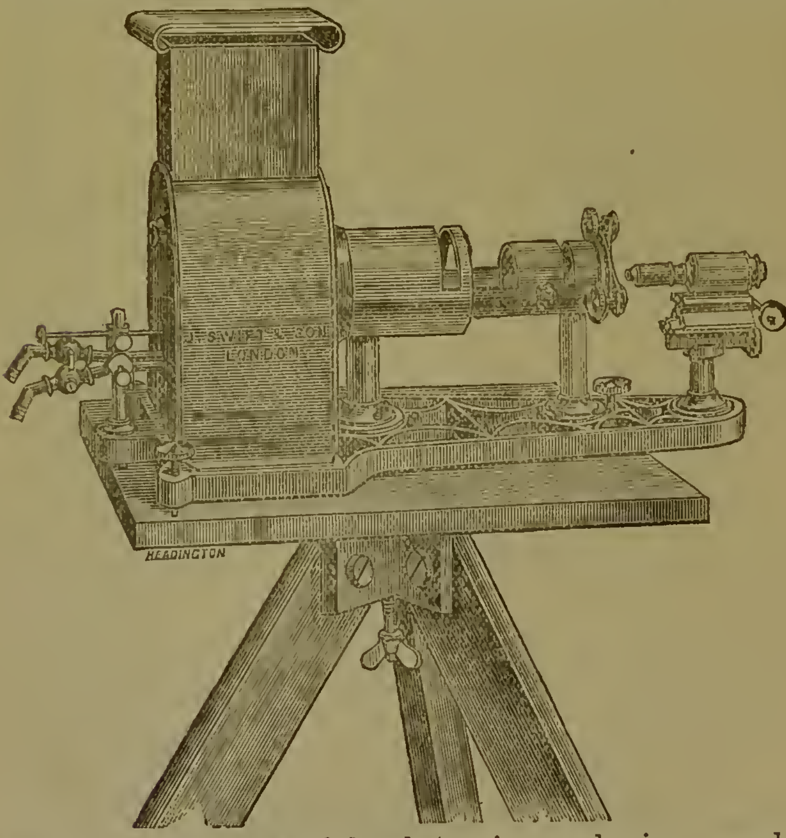
a, Magnesium lamp; *b*, condensers; *c*, microscope; *d*, focussing rod attached to fine adjustment; *e*, support of microscope; *f*, support of focussing screen *g*, and moving backwards and forwards in a line with the microscope, either in guides or on rails; *g*, focussing-screen.



a, Electric light apparatus; an incandescent lamp might be substituted with advantage. The other letters same as in the figure above.

at his disposal, and can fit up an apartment specially for his work, perhaps this arrangement is the very best that can be used; it is, however, hardly suited to beginners. The references to each figure will suffice to explain the general arrangement of the apparatus.

The oxy-hydrogen microscope has frequently been proposed for use in photo-micrography, but no lantern-microscope as yet brought before the public has really given satisfactory results. However, lately, Messrs. Swift and Son have brought out an oxy-hydrogen gas microscope, which is figured below, and which



is said to meet the wants of the photo-micrographer in a remarkable manner. It is of an entirely new construction, with which

the ordinary micro-objectives, from 4 inch to $\frac{1}{4}$ inch, can be used. The gas jet is so constructed that it can be easily adjusted for convergent or parallel light without the necessity for opening the lantern. The perforated metal base upon which the whole is mounted allows a continuous current of air to pass through for the purpose of keeping the lantern cool. The frame or base stands upon three adjusting screws to arrange the position of the disc of light. The tube into which the supplementary apparatus is adapted, is cut open to enable these parts to be dropped into position, and which are then covered by a revolving segment similar to the action of the breech part of the Martini-Henry rifle, thus preventing the necessity of displacing the stage, &c., to insert these in the ordinary manner. It has coarse and fine adjustments for focussing, which will work perfectly steady at any distance from the screen. The stage has rectangular movements by means of milled heads, and the clip holding the object will clamp either the thinnest slide or the thickest zoophyte trough. The alum trough for stopping the heat can be used between the light and condenser when convergent rays are required. For parallel light it is placed in the opening in front of the condensers, thus, when the alum trough is not required in this position, the opening is closed by an inside revolving tube.

CHAPTER V.

DEVELOPMENT.

The development of a photo-micrograph does not differ much from that of other negatives, but requires somewhat more patience, as the image on a properly exposed plate is usually very slow in appearing, and must not be "forced" in any way. Any ordinary dry-plate developer may be used, but the writer has found that known as the sulphite developer answer best.

Ferrous oxalate is recommended by some photo-micrographers, notably by Dr. Sternberg, but is hardly sufficiently "elastic" to satisfy all requirements. It has the great merit of being clean and simple, while it never stains the negatives, as some preparations of pyrogallic acid do; but the operator will find that with this developer he has very little control over the development. In fact, the development is so mechanical, that some operators, like Dr. Sternberg, are content to place the plate in the solution, and let it take its chance. No one who has become used to pyrogallic acid will ever care to use ferrous oxalate, and the writer would not advise the beginner to use it, but at once to master the difficulties of pyrogallic acid and ammonia.

However, as some may prefer to try what can be done with ferrous oxalate, the formula for this developer is given here:—

Saturated solution of ferrous sulphate	...	1 part
Saturated solution of potassic oxalate	...	3 parts

The potassic oxalate should be neutral, but as it frequently is alkaline, a few crystals of oxalic acid may be added, until the solution is neutral to test paper. The ferrous sulphate should be added to the potassic oxalate, not *vice versa*. A solution of potassic bromide, 20 grains per ounce, should be kept at hand. A few drops of this will be useful to add to the developer in case of over-exposure.

For several years the writer used the following form of the pyro developer, which will be found to give good results :—

A.—Pyrogallic acid	¼	ounce
Sodic sulphite	1	,,
Water	40	ounces
Citric acid...	1	dr.
B.—Liquor ammoniæ	½	ounce
Potassic bromide	40	grains
Water	40	ounces

These form stock solutions, and will keep indefinitely. Both had better be kept in stoppered bottles. The sodic sulphite must be good; otherwise, good results need not be expected. Some writers have stated that sodic sulphite produces green fog, but this is hardly correct. The writer had used the sulphite developer for over two years before he saw anything of green fog. He had been accustomed to buy his chemicals from a good chemist, and had always paid 1s. 6d. per pound for sodic sulphite. Happening once to require some immediately, he purchased a sample from the nearest shop, and paid 6d. per pound for it. It was wretched looking stuff, but he made it up. On developing, every plate was covered with a glorious sheen of green fog. Happily, this was completely got rid of by Mr. H. Farmer's solution, which will be described further on. *Moral:* Buy the best chemicals from a good chemist, and do not grudge the price paid for them.

Of late the writer has used the following modification of Dr.

Stolze's potash developer, which appears eminently suited to the requirements of the photo-micrographer :—

No. 1.—Pyro Solution.

Warm water	2 ounces	
Sulphite of soda (pure) ...	2 ,,	(437 grs. to oz.)
When cold add—		
Sulphurous acid	2 ,,	
Pyrogallic acid	½ ounce of 218 grs.	

No. 2.—Potash Solution.

A.—Water	4 ounces
Pure carb. of potash (437 grs. to oz.)	3 ,,
B.—Water	3 ,,
Pure sulphite of soda (437 grs. to oz.)	2 ,,

Combine A and B in one solution. For rapid exposures, take 3 ounces water, and add to it ½ ounce of No. 1, and 3 drachms No. 2. This suffices for a whole plate. For very rapid exposures the developer may be used even stronger. To develop plates over-exposed, begin with only a few drops of No. 2, and if the over-exposure has been great, dilute the developer with an equal bulk of water. The elasticity of this developer is very great, and by using it in strong or dilute form, great latitude of exposure is admissible. In a letter to the Photographic News the writer attributes the following good qualities to the potash developer :—1st. Freedom from noxious fumes; 2nd. Cleanliness—it stains neither the fingers nor the plates; 3rd. It is completely under control; 4th. No bromide nor other restrainer is required; 5th. It gives clear, brilliant, quick-printing negatives; 6th. It is far more powerful than the ordinary pyro and ammonia developer, hence far more suitable for instantaneous work and for photo-micrography. No forcing of the image is necessary; and the details in the shadows of an instantaneous picture come out with due strength. However, it is absolutely necessary to use *pure* carbonate of potash, not

necessarily *pure for analysis; pure* sodic sulphite, as common sulphite is worse than useless; and really *strong* sulphurous acid. The photo-micrographer had better make the sulphurous acid himself, by acting either on copper or hyposulphite of soda, with sulphuric acid. The advantages gained by having the sulphurous acid full strength fully compensate one for the little trouble incurred in making it.*

Another modification of the pyrogallic developer is given by Mr. S. Fry, as follows:—

A.—Acid pyro	... ...	1 ounce
Saturated acid solution of sodic sulphite	... ...	12 ounces
B.—Ammonium bromide	... ...	300 grains
Ammonia liquor	... ...	2 ounces
Water	... ...	12 ,,

Take 1 ounce of A; put it in a 20-ounce bottle, pouring on it 15 ounces of water. Do the same with B. Use equal parts for developing.

A new developer has lately been introduced by Messrs. Egli and Spiller—hydroxylamine hydrochloride. The following is the formula:—

A.—Hydroxylamine hydrochloride	...	32 grains
Citric acid...	... ...	15 ,,
Potassium bromide	... ...	20 ,,
Water	... ...	1 ounce
B.—Caustic soda	... ...	1 drachm
Water	... ...	1 ounce
C.—Potassium bromide	... ...	20 grains
Water	... ...	1 ounce

For a $7\frac{1}{2} \times 5$ plate the film is first soaked for about one minute

* Anhydrous sulphurous acid is now an article of commerce, and can be purchased in syphon bottles.

in $3\frac{1}{2}$ ounces of water, containing 1 drachm of A, about 20 drops of B is then added, and if necessary an extra ten or so. Should the image show signs of over-exposure, or if the plate is one of the specially sensitive kind, a few drops of C must be used to restrain the action still more. The advantages resulting from the use of this developer are the following:—

1. The image is of a *wet-plate* tone, perfectly free from stain or deposits.
2. A great variation of exposure is admissible.
3. The solution is not acted upon by the atmosphere, and therefore does not deteriorate during development from external causes.

To develop a plate, proceed as follows:—Have a good-sized lamp glazed with pale red glass, not with the black abomination generally called "ruby," which is almost opaque to light. A good lamp may be made from any kind of box, by fitting to it a sliding pane of red glass in place of the lid, and putting a small paraffin lamp therein. A chimney should be made at the top, to ventilate the box. This arrangement will give a flood of light without endangering the plate. The writer always develops close up to the lamp, and has never yet fogged a plate. If the operator cannot see what he is doing, he need not expect good negatives, but may reasonably look for indication of failing eyesight after a few months' work. So, to get good negatives, and save temper and eyesight, have plenty of light of the right sort. No light is really non-actinic, and much of the "ruby" glass in use is quite as unsafe to use as the yellow glass used in developing wet collodion plates. Yet, once in the developer, even yellow glass may be used with complete safety. It is only while the plate is dry that exposure to a strong light is likely to act injuriously. Thus, in changing plates, or in taking them from the slides to develop, let the lamp be shaded or turned down; but while developing, every detail must be clearly seen.

To proceed. Place the developing dish near the lamp; pour into the developing cup, for a half-plate, 1 ounce of the pyro-

gallic solution, and ½-ounce of the ammonia and bromide. Place the plate in the dish, and pour over it the mixed solutions. If the image runs out rapidly, pour the developer off, and make up a fresh developer of 1 ounce pyro and 1 drachm ammonia and bromide. If, after this, the detail does not come out satisfactorily, pour the developer back in the cup, and add more ammonia. By varying this mode, plates that have received

PARASITE OF OX. 2-inch obj.

thirty times the correct exposure may be satisfactorily developed. They will hardly have the brilliance and "pluck" of a properly-exposed negative, but will yield fair prints.

If the image does not make its appearance after it has been in

the developer about a minute, add the remaining ½ ounce of the ammonia solution. The image will then slowly appear, if the plate has been properly exposed; but if under-exposed, only further doses of ammonia will bring it out. In the latter case, take no further trouble with the plate, but at once expose another, for an under-exposed plate is simply useless.

It will be found, in developing some negatives, that one part will develop more readily than another, and become so dense as to be quite unprintable. The photograph given above (parasite of ox) is an example of this. On developing, the body appeared first, and became of an alarming blackness before the legs had got little more than their outline. The developer was at once thrown off, and the negative well rinsed in water. Fresh developer was made up, and the tray tilted up, so that when the negative was again placed in the dish the developer would cover the parts only partially developed, which in this case were the head and legs. The dish was gently rocked all the time, and the negative, when finished, was of uniform density. By this means the after reduction of the negative was avoided.

If the development proceed satisfactorily, don't be in any hurry to take the plate from the development; over-development will not do much harm, while the contrary would ruin it. When all the details are well out, examine the plate, by holding it up before the lamp. Should it prove sufficiently dense, rinse it in water, and place it for a minute in a solution of alum and citric acid; wash again, and put it in another dish containing hyposulphite of soda made up thus:—

Hyposulphite	4 ounces
Water	20 ,,

When the creamy bromide of silver is dissolved, which may be known by the plate becoming quite clear and transparent, place the negative in fresh hyposulphite for a few minutes; no fear need be entertained of the hyposulphite solution *weakening* the

negative. Then put the plate in running water for half-an-hour. This will be sufficient, but any trace of hypo will be got rid of in the next bath :—

Alum	2 ounces
Citric acid	1 ounce
Water	20 ounces

This solution will also harden the film, and render it less liable to injury from scratches or wet. The final immersion in alum should be regarded as absolutely necessary. It will brighten up the negative, removing any stains which the developer may have left, and make it "quicker printing."

The negative should not be dried too rapidly. In fine dry weather it can be best dried by placing it out of doors. In winter time, the writer stands his negatives on a warm mantel-piece, where they dry in one or two hours. The only precaution to be observed is, that the plate should have previously been soaked in the alum bath for at least five minutes; otherwise, if the film be composed of soft gelatine, the heat of the mantelpiece is apt to melt it.

CHAPTER VI.

DEFECTS IN THE NEGATIVE.

As the defects in photo-micrographic negatives are very numerous, it may be well to mention the chief, and their remedies, when such exist.

1. *Unequal Illumination.*—This is very apt to occur when using very oblique light, but may happen also with central light, from improper arrangement of condensers, &c. This defect may be known by the negative being dense on one side of the plate, and thin on the other. Do not blame the plate-maker for improperly levelling his plates; this defect sometimes occurs, but very rarely. If the difference of density on each side is not very marked, it may be remedied by using matt varnish on the thin side of the plate, to diffuse the light when printing. Adding a little yellow dye to the varnish often improves the result, but in all cases the rough edge of the varnish should be softened by the use of a little alcohol or ether, or a nasty mark will be left on the print, just under the boundary line of the varnish.

2. *Too Powerful Illumination.*—In this case the object is "drowned in light," and the picture comes out flat and degraded. Remedy: take another negative.

3. *Reflection from the Apparatus.*—When the tube of the microscope is not lined with cloth or velvet, a bright central spot

may often be seen on the screen while focussing, and a corresponding black patch will be found on the negative, which will be worthless. When using the eye-piece, this defect will not be met with. Reflection from the camera will also ruin the negative, also using the eye-piece without the cap. Let the inside of the camera and microscope tube be a dead black.

4. *Access of Stray Light to the Plate.*—Probably through the connection of camera and microscope not being light-tight. Result—general fog. Use a thick black velvet hood to connect the microscope with the camera, and keep it in place with elastic bands.

5. *Green Fog.*—This may arise from the use of impure sodic sulphite, or, in the plain pyro developer, from using too much ammonia. Green fog appears to be a silver deposit, from the fact that certain silver solvents get rid of it at once. Bichromate of potash, or peroxide of hydrogen, may be used, but the writer recommends the following, which is given by Mr. Howard Farmer in the YEAR-BOOK for 1884 :—

A.—Potassium ferricyanide	1 ounce
Water	20 ounces
B.—Sodium hyposulphite	1 ounce
Water	20 ounces

First wet the negative if it has been dried. Pour a little of the hypo solution in a cup, and add a few drops of the ferricyanide solution. Dip a plug of cotton-wool in this mixture and sponge the negative rapidly with it; then plunge it in water, and wash well. All traces of green fog will have disappeared.

6. *Over-exposure.*—This should be controlled in the development. After-intensification rarely produces even tolerable negatives from over-exposed plates. If much over-exposed, don't waste time in trying to patch up the negative, but expose another plate.

7. *Under-exposure.*—There is no cure for this evil; destroy the negative and take another.

8. *Under-development.*—An under-developed plate is useless. Don't hurry the development, but be sure all possible detail has

PALPI OF MALE GARDEN SPIDER.

been worked out, and examine the negative for density before the lamp.

9. *Thinness.*—The negative appears fully exposed and developed, but is too thin to give good prints. In this case try

the effect of covering the back with matt-varnish, and print in the shade. Never intensify a negative before trying how it will print. Many a negative that appears too thin will give perfect prints. The negative from which the accompanying illustration of "Palpi of Male Spider" was taken furnishes a good example of this. This negative appears a mere "ghost," but prints well and strongly. Had it been intensified it would probably have been ruined. If the matt-varnish does not mend matters, the negative must be intensified. There is a choice of intensifiers, but the mercury and silver intensifiers are most generally used. The mercury intensifier is made as follows :—

A.—Saturated solution of mercuric chloride.
B.—Liquor of ammonia ... ... 10 drops per oz.

After soaking the negative in water, it is placed in the bichloride solution until it becomes uniformly white. If requiring only slight intensification, it must be left in only a few seconds, or it will become too dense. Then wash well for five minutes, when the negative must be placed in B, which will turn the plate to a dark colour. With a little experience, this intensifier will be found very useful, but all intensification should be avoided if possible. Look for good results to the development alone, and let intensification be merely a last resource.

Other intensifiers are potassium sulphide and ammonium sulphide; either salt may be made up to the strength of 1 drachm to 20 ounces of water.

One of the best silver intensifiers is that given by Mr. W. Brooks, and is as follows :—"After the plate has been well washed from the hypo, place it in a weak solution of alum and citric acid solution :

Stock Solution.

Saturated solution of alum	10 ounces
Citric acid	1 ounce

For the solution above-named, I dilute one part to four of water, allow the plate to remain in it about five or six minutes; in the meantime, place in a developing cup about (say for a small plate) two drachms of the stock solution of alum and citric, and place in it about four grains of pyro; when dissolved, add a few drops of about a twenty-grain nitrate of silver solution."

This solution is to be applied to the plate until sufficient density be obtained; when the plate is washed, it is placed in the hypo bath for a few minutes, again washed, and finally treated with alum and citric acid solution to clear it. Plates thus intensified should not first be dried.

A very good intensifier for plates developed with potash is Dr. Eder's sulphate of iron and alum mixture. It should be applied immediately after fixing, or better still, before the creamy bromide of silver is quite dissolved out of the film. Equal parts of ferrous sulphate and alum are used. This intensifier appears to act as a stain, but is very useful when only slight strengthening of the negative is required.

If a negative appear too dense after mercurial intensification, it may easily be reduced to proper intensity by immersing it in a very weak solution of hyposulphite of soda—a 5 per cent. solution. It is necessary to watch the negative carefully on immersing it in this bath, or it may become too thin. As it is often difficult to hit the right degree of density with the mercurial intensifier, the after application of a weak hypo solution may save a valuable negative from being cast aside as useless.

10. *Too Great Density.*—This is more frequently met with when using the plain pyro developer. Perhaps the simplest agent for removing it is Mr. Howard Farmer's ferri-cyanide reducer given above in speaking of green fog. The plate, if dry, is soaked in water for a few minutes, then placed in the solution, and examined from time to time until sufficiently thin. Only a few drops of ferri-cyanide must be added, or the action will be too rapid. Then wash well in running water, and dry.

11. *Shrinking of the Gelatine.*—This may arise from the gelatine being too soft, or from heat being employed to hasten the drying, which is a great mistake. The shrinking may be slight, spoiling the fine microscopic detail, or may amount to actual distortion of the image. Either way, the negative is ruined; the photo-micrographer is therefore advised to use only plates prepared with hard gelatine. Since the use of the alum bath has become more general, frilling is not so common as formerly, and the photo-micrographer need hardly be cautioned against it. Still, to avoid this, as well as the more serious evil of shrinking of the film, any plates found to be prepared with soft gelatine should be rejected for microscopic work.

CHAPTER VII.

PRINTING.

The advice given in the introduction is here repeated: let the photo-micrographer make all his own silver prints, as in no other way can he hope for results of a satisfactory nature. The process is not difficult, and, when once mastered, the microscopist will have the pleasure of seeing his pictures *real* representations of the originals, instead of being little else than caricatures, which is often the case when the negatives are entrusted to another to print. A professional photographer may be able to produce perfect specimens of art from portrait or landscape negatives, yet fail entirely when he tries to print a photo-micrograph, simply from not understanding the nature of the object represented.

Ready-sensitized paper may now be procured of great excellence at a moderate price. The photo-micrographer should purchase the best obtainable, for the best costs at first very little more than the worst, and in the end costs really less, as there will be no defective sheets to reject, to say nothing of the superior quality of prints to be produced on good paper.

Some photo-micrographs look very well on *plain* paper—that is, on paper not albumenized. The paper can be purchased ready salted at any dealer's, and has merely to be sensitized on a nitrate of silver bath of suitable strength. Prints on such

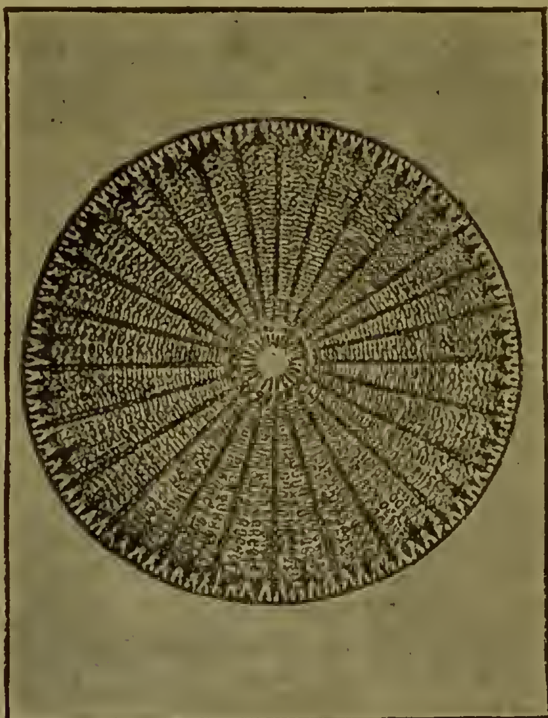
paper look very much like engravings, and are generally more admired by artists than prints on the ordinary highly glazed paper. However, where there is much delicate detail to be shown, there is nothing like a good double-albumenized paper.

In the winter, when printing is both slow and troublesome, the new gelatino-bromide paper of Morgan will be found very useful. This paper is very sensitive to light, so it must be cut up and placed in the printing-frames in the dark room. Exposures are best effected by lamp-light, and for ordinary thin negatives an exposure of a few seconds to lamplight will be quite sufficient. Very dense negatives may require an exposure of one or two minutes. The image is developed by immersing the paper in a solution of ferrous oxalate. Full directions for using this paper accompany each packet. When the right exposure for a particular negative has been found, it is possible to make a large number of good prints in a very short time. The colour of the image is a cold black, but a warmer tone may be given the print by treating it with the ordinary bichloride of mercury and ammonia intensifier.

Frequently a photo-micrographic negative may require some little preparation before it is ready to print. For instance, diatoms being, as a rule, very transparent objects, require a short exposure. This exposure, though sufficient to bring out the detail in the diatom, is not long enough to give proper density to the background, which should appear white in the finished print. In this case the best plan is to "paint out" the background, at the back of the negative, with Bates' or Fallowfield's black varnish. It will be easy to follow with the brush the regular outlines of the diatom; but should any varnish trespass on the edges, don't wipe it off, but let the whole dry. When dry, hold the negative up to the light, and go round the edges of the image with a fine-pointed penknife, cutting away in an even manner any varnish that intrudes on the edge of the picture. The varnish should come exactly up to the edge of the

image; there should be no intervening space, or failure will ensue. The negatives treated thus should always be printed in the shade—a powerful light would produce an objectionable black halo round the object. All objects which have regular outlines should be thus treated, if necessary.

The *Arachnoidiscus* figured below had an exposure of fifteen minutes, with Swift's low-angle one-fifth-inch, A eye-piece and



ARACHNOIDISCUS INDICUS × BY 300.

small microscope lamp. This exposure brought out the diatom sharply and with due printing density, but the background was weak, and would have printed in with a most objectionable blackness had not the plan of "painting out" been practised.

Parts which come out insufficiently dense, may be

strengthened on the film side of the negative with a soft black-lead pencil. This is best done after the negative has been varnished, using a little turpentine to roughen the part to which the pencil is to be applied.

Local reduction has often to be effected, and can easily be done by using the ferricyanide reducer given above. Wet the negative thoroughly; when the excess of water has drained off, dip a fine brush in the solution, and apply to the over-dense parts. As each dense place is reduced, dip the negative in water to stop the reducing action, and proceed with the next part.

It will often be found that, no matter what skill may be expended on the negative in strengthening weak parts and reducing dense ones, it is impossible to get a harmonious print. Some parts will print in strongly long before other parts are done, and no choice seems to be left but to under-print some portions, and over-print others. In this case, good prints may generally be obtained by the judicious application of cotton-wool. When the quick-printing portions are done, cover them with cotton-wool, place the printing-frame in the sun, and print in the denser parts as quickly as possible. In the finished print there should be no mark left by the wool, but all should appear as if printed in at the same time. The writer once photographed a section—transverse—of hazel, which was thicker one side than the other. As the negative showed splendid detail, he did not like to destroy it, but made use of cotton-wool, covering the weak part, corresponding to the thicker side of the section, with cotton-wool as soon as sufficiently printed, and leaving the dense part, which corresponded to the thinner side, to print further in a strong light. In the finished print there was not the slightest indication of the unequal density of the negative.

The two photographs here given, male and female flea, illustrate the case in point. Owing to the unequal contrast in density of the body and legs, these negatives are somewhat difficult to print properly. When the body is properly printed,

the legs, being very dense, are not printed in; and if the print be exposed until the legs gain sufficient density, the body is quite burnt up. Yet most harmonious prints can be got from these negatives by covering up the body with cotton-wool as soon as printed sufficiently, and exposing the legs for a longer period. In the insects themselves, the legs are very transparent compared with the body, which, during life, is of a dark brown-black, but which becomes a strong amber colour when the insect is mounted in balsam, and is thus somewhat difficult to photograph properly. If the specimens are intended for photography, they should be bleached by allowing them to lie in turpentine for some weeks, until they become of a lighter colour; but nothing short of the chlorate of potash bleaching solution can quite get rid of the objectionable yellow colour. The specimens photographed by the writer were supplied by Mr. Edmund Wheeler, who had a most extensive stock of microscopic slides, which, from their perfection of finish, were well fitted for the use of the photo-micrographer. Mr. Wheeler's stock is now held by Messrs. Watson, of High Holborn, who would, doubtless, be able to supply the student with many of the excellent preparations for which Mr. Wheeler had such a good reputation.

CHAPTER VIII.

PREPARING OBJECTS FOR PHOTOGRAPHY.

Many microscopic objects are totally unfit for photo-micrography, as the beginner will soon discover if he attempt to photograph indiscriminately the objects in his collection. It does not follow, because an object looks very beautiful under the microscope, that it will yield even a passable photograph. It may look all that can be desired on the stage of the microscope; all its different parts may be defined clearly with diffused light; yet its colour, or the strong contrast of one part with another, may be such as to render a photograph of it quite impossible. Take, for instance, an object mentioned in our first lesson, the tongue, or proboscis of a fly; satisfactory photographs of this object are not common, simply because they have been taken from the specimens usually met with in collections, which have been prepared to give the best effect when seen through the microscope, where the strong contrast in depth of colour between the lobes of the ligula and the thick portion of the maxillæ and maxillary palpi is no defect, but positively an advantage. When such a specimen is photographed, its unfitness is clearly seen; the thin, transparent lobes are usually much over-exposed long before the darker parts of the ligula have received their proper amount of light; in short, no exposure will suit this object as a whole. It is true, a sort of makeshift may be employed, and fair results gained, by shading

the transparent parts during exposure, keeping the shade in gentle motion all the time, during half or three-fourths of the exposure, when the whole may be exposed. It is far more satisfactory, however, either to select one of these tongues from a large number, or prepare one specially, so as to subdue these undesirable contrasts, and bring the whole object more into harmony as regards density.

The beginner in photo-micrography is strongly advised to make his own microscopic preparations. A microscope can never be much more than a pleasant toy if its possessor rely wholly on purchased slides. To own even a moderate collection of slides prepared by the professional mounter will cost a large sum of money, and when these have been examined a few times, their interest is gone, and the microscope is laid aside for want of objects to examine. But when the student prepares his own objects, his microscope becomes to him a continual source of pleasure and instruction. His slides, in the majority of cases, may not be equal to those professionally prepared, and they will certainly lack that exquisite finish which constant practice in their preparation alone can give; but for the purpose of study, and especially for photo-micrography, they may be equal to, or even better than, anything that can be purchased from the optician. Then, with practice, the student will so far improve that he will find his own preparations so much better for his special purpose, that he will rarely visit the optician's shop for slides, unless it be to purchase some object that cannot be procured elsewhere, or one which may be beyond his own powers to prepare. That there are such objects, it cannot be denied; and we may perhaps place anatomical preparations in the list of objects better left to the experience and skill of the professional preparer. As the student will not require his objects to be mounted in fancy style, he may prepare slides of such diatoms as he can find in his walks, or obtain by exchange, small as these objects are, purchasing only the rarer forms, or such as are pre-

pared especially as test-objects. Practice in preparing and photographing minute objects, like diatoms, is not only desirable, but necessary, to give the beginner complete command over his microscope and camera.

The apparatus required in the preparation of microscopic objects is neither cumbrous nor costly. The following list includes most of what the beginner will require:—A spirit lamp; needles mounted in wooden handles; glass slides, 3 in. by 1 in. (these should be of plate-glass with ground edges); circles and squares of thin cover-glass, the thinner the better; solution of potash, commonly called liquor potassæ; methylated spirits; spirits of turpentine; some pure benzol (not benzoline); nitric, sulphuric, and hydrochloric acids; chlorate of potash; a bottle of balsam, or balsam and benzol; glycerine; gelatine; fine and coarse emery; a glass plate (preferably *plate-glass*) about a foot square, and one of cast-iron the same size, for grinding down sections of horn, bone, or rocks; a pair of scissors; a sharp knife; a pair of forceps; and a dozen brass clips for holding the covers on the slides, will also be required.

It is best to keep the balsam in a bottle fitted with a wooden stopper, through which a glass rod may be passed. The end of the rod may be kept above the balsam when not in use. When it is required to take some balsam out, the rod can easily be pushed down until it just dips below the surface, and a small quantity taken out without soiling the neck of the jar. Corks should not be used, as they are apt to stick fast, and, by crumbling away, fill the balsam with small fragments which are difficult to remove. By keeping the glass rod always in the bottle, it will remain clean, which would not be the case were it kept elsewhere; and the learner will soon find that cleanliness is absolutely necessary in microscopic work.

Newly-purchased slides and covers are always dirty. Water will not always effectually cleanse them; they should therefore be washed in a solution of caustic potash, ammonia, or soda.

This will free them from impurities; but the slides should afterwards be well rinsed in pure water, or some of the alkali will remain on the glass, and prove as great a hindrance as the dirt.

Microscopic objects are mounted in three different ways: 1. Dry. 2. In a gum, such as balsam or dammar. 3. In some fluid, such as water, glycerine, or alcohol. Dry-mounted objects, being usually opaque, are not well suited for photography, unless the operator has more than common dexterity in the management of reflected light. In the case of very transparent objects, however, such as diatoms, dry-mounting is far the best, as the use of balsam or glycerine does much to obliterate fine markings, on which the interest of the object perhaps entirely depends. Balsam or dammar will most generally be used as the mounting medium, as these gums render an object mounted in them more transparent, and can be used in most cases where they exercise no solvent action on the preparation. Insect preparations, vegetable tissues, rock sections, crystals of various salts, are, as a rule, photographed to best advantage when mounted in balsam.

As insect preparations are of perhaps more general interest than any other, and are more easily photographed, we shall treat of preparing these objects for photography in our next chapter.

CHAPTER IX.

PREPARING ENTOMOLOGICAL SLIDES.

A glance at the catalogues of the professional preparers will show how popular are insect preparations. Nor is this surprising. The marvellous beauty of form, the gorgeous colours, the elaborate workmanship displayed in the construction of their various organs, together with the minute size of many of the insect tribe, all render them fit objects for microscopic study. Many of their beauties are apparent to the unaided eye, but under the microscope they are increased tenfold; while others alone reveal themselves to the scrutiny of the magic tube. But for it, the delicate mosaic of the butterfly's wing, the mysteries of the gem-spangled elytra of the diamond beetle, the myriad-facetted eye, common to the whole insect world, and all the wonders of their internal structure, would remain hidden to us.

As insects vary so much in size, colours, and texture, the modes of preparing them for photography must also vary to suit the subject under treatment.

1. *Opaque Mounting.*—This method is alone available in some cases, as the application of balsam or any medium would not only diminish the beauty of the specimen, but even prove destructive in effect. Such objects as scales, such as those of butterflies, the Podura and Lepisma, as well as some wings which are very transparent, as well as small insects like the Tingis and

Thrips, which can be successfully photographed by reflected light, should be mounted dry. In the case of small flat objects, as scales, no cell will be required; all that is necessary is to place the scale in position on the slide, and cement a thin cover over it. Larger objects will require a cell, which, for photography, had better be of glass. Glass cells are sold at a cheap rate, look well, and have the advantages of allowing light to pass through their sides, which is often desirable. They can easily be manufactured at home by any one who has a little skill, by cutting rings from glass tubing with a sharp flat file. Various cements may be used for attaching the cell to the glass slip; marine glue is the most trustworthy, but is sometimes difficult to manage, as it requires a strong heat to melt it. Gold-size, when good, is equally reliable, but the various cements which have been used of late years for mending broken china and glass, such as coaguline, appear to be quite satisfactory, and, being colourless, look best when used with glass cells.

2. *Mounting in Balsam.*—Whole insects are usually prepared and mounted in the following way:—Having killed the insect, either by means of the cyanide bottle, or by immersion in spirits, it is set out carefully between two glass slides, which are tied together and put in a strong solution of potash—caustic potash one ounce, water twenty ounces. Here it must remain for some time according to its colour and texture; but a frequent examination of the specimen is necessary, as some insects dissolve into a jelly if kept in potash too long. One or two days will suffice for most specimens, but others will take longer. When it becomes sufficiently soft, it is taken out of the potash, placed in a saucer of pure water, and gently pressed with a soft brush until the contents of the thorax and abdomen are expelled. It must then be washed with fresh water until quite clean, when it must again be set out on a slide in the position which it is finally to occupy, covered with a square of thin glass, and tied down with thread. Here the treatment may vary. The older

method was to keep the slide in a warm place, under cover, until the preparation became quite dry, and then immerse it in turpentine.

The objection to this plan was that the insect became full of air, which it is almost impossible to expel, unless by the aid of an air-pump. The better method is to drain all the water from the insect after washing, using blotting-paper if necessary, and then immerse it in alcohol and water for about a day, and after that in pure methylated spirit to displace all the water. A second dose of pure spirit may be necessary in some cases. The whole of the water will thus be removed by the spirit, which will also render the preparation so firm that, on the application of the balsam, it will not alter from the position in which it was set. When quite free from moisture a few days' soaking in turpentine will give most specimens the necessary transparency. Some insects and parts of insects may, however, require to be left in turpentine for several weeks before they are fit to mount.

The tissues of some dark-coloured insects are best treated with some bleaching agent immediately after their removal from the potash solution; one of the best is as follows:—

Hydrochloric acid	10 or 12 drops
Chlorate of potash	$\frac{1}{2}$ drachm
Water	1 ounce

This will remove the objectionable strong browns and yellows of the chitinous portions, which are so fatal to obtaining a good photograph. By examining the object occasionally, the right amount of transparency will be gained; but it is best not to let preparations remain too long in the bleaching solution, because if too transparent they will be as difficult to photograph as if too opaque. The writer recently photographed two splendid fly's tongues, or ligulæ, specially prepared by Topping. These were selected out of seventy-two similar preparations; but while

both were perfection as microscopic objects, or for exhibition in the lantern microscope, only one was fit for photography. The other had been bleached too much, and was too thin to give a satisfactory photograph.

When the necessary transparency has been attained, and after the object has been successively treated with alcohol and turpentine, it is ready for mounting. A solution of balsam in benzol is better than pure balsam in many ways. The solution may be prepared by "baking" pure balsam in a slow oven until it becomes quite hard on cooling, and then dissolving in benzol, or may be purchased at the shop of any optician. The insect, or part of one, is removed from the turpentine and drained, placed in position on a slide, a cover-glass placed over it, and a small quantity of the balsam solution applied to the side, when it will be drawn under by capillary attraction. By a little care, air-bubbles may be entirely avoided. The slide is then put aside until the balsam has become quite hard, when it may be cleaned for the cabinet, and ornamented with rings of coloured varnish, as the mounter's taste may dictate.

Of late years many microscopists have objected to the "squashing" process usually employed in mounting insects, as, in many cases, it deforms and distorts the preparation almost beyond recognition; and now many amateur and professional preparers mount insects without pressure, first gaining the necessary transparency by prolonged immersion in turpentine, and finally mounting with balsam in a cell. Objects thus mounted are very beautiful, especially when illuminated with the paraboloid or spot-lens, but are somewhat difficult subjects for photography, unless a very low power, such as a five-inch, four-inch, or three-inch, be employed, as great penetration is required.

It is best, when engaged in mounting insects specially for photography, not to mount indiscriminately any pretty object, but to set up a type-series, to illustrate the class *Insecta*, which,

when photographed, would have a real scientific value. Something after the following style might be attempted :—

1. *Coleoptera.*—Many of the smaller species can be set up whole, after bleaching in the chlorate of potash mixture. A few feet may also be mounted; the paddle-foot of *Dyticus*, the broad-padded foot of *Timarchus*, and the type-foot of *Carabus*. Some of the antennæ, as those of *Melolontha*, are also well worth mounting and photographing.

2. *Dermaptera* (the earwigs).—A specimen may be mounted whole for a five-inch objective: if possible, with the wings expanded. This subject will not require more than a few hours treatment with potash.

3. *Orthoptera* (the cockroach).—*Blatta Orientalis* is a good type, although not a true English insect. Almost colourless specimens may be found in kitchens which these creatures haunt. These will require no preliminary bleaching.

4. *Thysanoptera.*—The diminutive insects so abundant and so troublesome in hot summers—insects which will persist in crawling over one's face, and into one's mouth and eyes, which swarm everywhere and on everything—constitute this order. One of the largest, *Phlaeothrips coriacea*, measuring about $\frac{1}{14}$ of an inch in length, may be set up whole in balsam.

5. *Neuroptera.*—A portion of the large facetted eye of the dragon-fly may be mounted flat on a slide in balsam, and will form a very instructive photograph.

6. *Trichoptera.*—The larva of the caddis-fly may easily be prepared. The internal parts must be removed, when, after washing and treatment with turpentine, it is ready for mounting. The mature caddis-fly may be set up whole.

7. *Hymenoptera* (bees and wasps).—The wings, showing attaching hooklets, may be mounted dry or in balsam. The feet will require to be bleached strongly, as most of the *Hymenoptera* are strongly coloured. The modified ovipositor, called a sting, should be cut from the insect carefully, so as to have the poison-

bag attached. The stings—for there are two—lie enveloped in a case of brown chitine, from which they may be dislodged by a fine needle. The poison-bag, owing to its extreme transparency, must be stained—not with blue, as in many professional preparations, but with brown. Bismarck brown is, perhaps, as good as any. Sufficient stain should be used to give this part as nearly as possible the same colour as the stings.

The saw-flies show another modification of—or, rather, addition to—the real ovipositor. This consists of a sawing apparatus, composed of four saws—two small and two large ones, the former fitting into the latter. This object is rather difficult to photograph when set up in balsam, as it becomes too transparent. A well-mounted dry specimen will give more satisfaction.

8. *Lepidoptera* (or butterflies) are interesting from their finely marked scales, which form tests for low powers. They should be mounted dry.

9. *Homoptera* (frog-hoppers and *aphides*).—The former possess saws, which may be prepared like those of the saw-flies.

10. *Heteroptera* (or bugs).—The "beak" of *Cimex lectularius* and the oar-foot of the water-boatman may be mounted in balsam.

11. *Aphaniptera* (or fleas).—These insects, to be successfully mounted, require a severe treatment with potash, and a long soaking in turpentine. Preliminary bleaching in the hydrochloric acid mixture is, perhaps, best to get rid of the yellow colour, which renders them difficult to photograph satisfactorily.

12. *Diptera* (or flies).—The feet of the dark-coloured species will require bleaching with chlorate of potash. The "tongues," or *Ligulæ*, should also be bleached, but *not too much.* The proper way to mount a fly's tongue is to set it up in a shallow cell, *without pressure.* The specimens usually sold, being mounted flat, are distorted, and give an improper idea of the real shape of the organ.

CHAPTER X.

PREPARING VEGETABLE TISSUES FOR PHOTOGRAPHY.

Dry-mounted vegetable preparations are not of much use to the photo-micrographer, except it be certain scales, such as those of the *Deutzia*, which can be successfully photographed with a low power by reflected light. In most cases the use of a bleaching liquid is necessary to get rid of the colouring matter, which must be removed before the tissues can be set up as transparent objects. The following bleaching liquids may be used :—1, Nitric acid; 2, methylated alcohol; 3, chlorinated soda.

1. Nitric acid must generally be used in a very dilute form, as many vegetable tissues, even those strongly impregnated with silica, are destroyed by it when pure. The stems of grasses, horsetails, and even leaves, as those of the *Deutzia*, may be bleached by gently heating in very dilute nitric acid. When the object appears sufficiently transparent, it must be well washed in distilled water to remove all trace of the acid, floated on a slide, and dried under cover. If the acid be used too strong, the object is decomposed; while if the washing be imperfect, crystals will form in its substance, and render it useless.

2. Soaking in alcohol does very well for many objects, such as cuticles, and thin, semi-transparent leaves. They should be left in alcohol for some hours; and when they have lost most of

their chlorophyll the alcohol must be poured off, and some fresh added, until the objects become white. They may now be transferred to benzol or turpentine for some hours, when they are ready for mounting. Boiling in alcohol is hardly advisable, for although it considerably hastens the bleaching, it tends to make all plant-tissues too brittle for mounting.

3. The best method of bleaching vegetable tissues is by means of chlorinated soda. The solution is prepared as follows :—Three or four ounces of good chloride of lime are taken, and put in about a quart of water. Stir the mixture a few times, and allow the sediment to settle ; after this the liquid had better be filtered through coarse filter-paper ; this is better than pouring the clear liquid off. Next, pour a strong solution of carbonate of soda into the chloride of lime solution, so long as a precipitate takes place, and allow the precipitate to subside. When clear, the solution should be tested with a few more drops of carbonate of soda, to ascertain if all the lime have been precipitated ; if not, more should be added, until no lime be left in the solution. Most of the solution, when clear, can be poured off, and must once more be filtered ; after which it should be stored in black or dark-coloured bottles, and well-corked, since both air and light speedily bring about decomposition.

A series of small glass pots should be provided to bleach the specimens. Shallow pomade pots are very suitable. Before the leaves are immersed in the fluid, it is best to wash them in clean water with a soft brush, since all leaves are more or less covered with fine dust, which will sink into their substance if not removed when they are fresh. When they are quite clean, they may either be put in the bleaching liquid at once, or put between clean blotting-paper to dry. Dried leaves, as a rule, bleach more rapidly than green ones.

When a leaf happens to be more deeply coloured than usual, it is a good plan to immerse it in alcohol until most of the colour has been removed. This much facilitates the bleaching process.

The time which tissues require to be soaked varies considerably. Some become translucent in a few hours, while others take many days; others will show green patches which obstinately refuse to be bleached. In this case, remove the leaf, wash it well, and place it in alcohol for some hours. In this way all the chlorophyll will be dissolved out, when the soda solution will complete the process. Care must be taken not to put too many leaves at a time into one vessel; three or four is the average number.

When properly translucent, the leaves or tissues must be removed from the soda solution, and washed in distilled water, changing the water every few hours. If the tissues do not contain Raphides, the addition of a little hydrochloric or nitric acid to the second or third washing will increase their transparency. *Sulphuric* acid must not be used, or crystals of sulphate of lime, which is only slightly soluble in water and acids, may be formed in the tissues, and cannot be removed.

About twenty-four hours is necessary to properly wash the leaves; less time is not sufficient, and a longer immersion tends to disintegrate delicate tissues. The washing completed, they should be placed in alcohol, in which they must remain for some hours, and afterwards be transferred to turpentine, until required for mounting.

The above bleaching process must be applied to sections of wood which are too strongly coloured for photography. It is hardly necessary to observe that all sections which are to be photographed should be of extreme thinness. Many which answer very well for examination under the microscope are far too thick for the photo-micrographer. Light-coloured sections, such as those of white pine, require merely saturation with benzol before mounting in the balsam solution. A section of deal, to show the characteristic "discs," should be mounted dry.

Spiral vessels, scalariform tissue, &c., will require but little treatment; the former, after drying and washing in alcohol and benzol, may at once be set up in balsam.

Cuticles may be prepared in the same way. In the case of very transparent tissues, staining will be of great use. Judson's dyes answer very well for this purpose, but all blue stains should be avoided in objects intended for photo-micrography.

Plant-crystals, or raphides, may be prepared either *in situ*, or separately. When mounted *in situ*, bleaching with alcohol is alone admissible. Raphides may be obtained from most plants by laying a leaf or stem on a slide, with the cut end about the middle; a gentle rolling pressure with a pencil will squeeze the juice and raphides out on the glass. Wash with alcohol, pour over a little turpentine, and mount in the usual way.

The following furnish good examples of raphides. Duck-weed, the onion, the willow-herb, the galium, or goose-grass. The large prismatic crystals of the onion or garlic polarise splendidly, and show better in a photograph when polarised light is used. In fact, many objects that are far too transparent to make good photographs, can be easily managed by putting on the polariscope. When this is of no use, a piece of fine ground glass, or oiled paper, immediately below the slide, will be of great service in softening the light. This will prolong the exposure, but give results that could not otherwise be attained.

For instruction as to staining vegetable tissues, the student is referred to a very valuable and practical paper by Dr. George D. Beatty, which appeared in "Science Gossip" for May, 1876; also to "Practical Microscopy," Chapter XII.

CHAPTER XI.

PREPARING SECTIONS OF HARD SUBSTANCES FOR PHOTOGRAPHY.

Many of the sections of hard substances, such as bone, rock, &c., sold in the shops, are too thick. Those prepared by the best lapidaries cannot be excelled; and if the student can afford to pay the high price charged for making these sections—from 2s. to 2s. 6d. each—he is advised not to undertake the labour and trouble of preparing them himself; for, although the manipulator may be skilful and patient, even when a machine is used, cutting sections of rocks is both tedious and laborious.

There are many excellent machines in the market specially devised for cutting sections; but they are all more or less expensive, and good work may be done by using very simple appliances, which we shall now proceed to mention. In the first place, procure an iron plate, preferably cast iron, about twelve inches square, and as thick as can be obtained. Next, a Water-of-Ayr stone, and one of harder texture, such as Washita stone. These may be obtained at any tool-shop. A Turkey stone is very good for sections of bone. For grinding down rocks, emery of various degrees of fineness will be required—buy one pound of medium coarse, one pound of medium fine, and one pound of flour emery.

To grind down a rock section, proceed as follows. Make a chip with a hammer, about one inch square, and not more than one-

eighth inch thick. Sedimentary rocks, such as limestones, may be thicker. Rub down the chip with coarse emery and water on the iron plate, until one side is perfectly flat. Remove the scratches by next rubbing the chip on a piece of plate-glass with fine emery, and then polish with water on the Water-of-Ayr stone; when quite smooth, wash it well, and let it dry. Meantime put some old, hard balsam on a glass slip, and warm it over a lamp until all the more volatile parts of the balsam evaporate, so that, on cooling, it becomes hard and tough. Don't *boil* the balsam, and don't continue the heat too long. When the balsam is properly hard, heat the chip on a metal plate, rub over it a little turpentine, and re-melt the balsam; lower one end of the chip slowly into the balsam, and press it down close to the glass slip. When the balsam is cold, rub down the chip on the iron plate with coarse emery until too thin to bear further friction. Very hard rocks may be brought down to the requisite thinness on the iron plate alone, and will only require a little polishing on a stone to remove the deeper scratches. Sections intended for photography should be cut down to the extreme of thinness, and *all* sections should be cut thin enough to read through when placed on the page of a book. When the section becomes too thin to bear any longer the friction of the coarse emery, wash it well, and grind it thinner on the glass plate with fine emery, and finish off on the Water-of-Ayr stone. If the section is strong enough to bear it, it should be removed from the slip on which it has been ground, and mounted on a clean slip. Warm the slide over the lamp sufficiently to melt the balsam, and push the section off with a needle into a cup of turpentine, and wash it carefully with a small soft brush. Now pour a little balsam and benzol on the clean slip, put the section upon it, add a little more balsam, and cover with a circle or square of thin glass.

Sections of bone or horn must be first cut with a fine saw, and ground down in the same way, only *no emery* must be used, and the iron plate will not be required, as the Water-of-Ayr

and Washita stones will prove sufficient. Before such sections are mounted, they should be soaked for a day or two in balsam and benzol to render them perfectly transparent.

Sections of soft rocks, and sedimentary rocks generally, are prepared and mounted in the same way, only no emery must be used, or it will imbed itself in the section and cause false appearances under the microscope. Most sedimentary rocks can be finished on the Water-of-Ayr stone. Some very friable rocks, or substances such as boiler incrustations, which readily disintegrate on the grinding-stone, must first undergo a preliminary hardening. Two hardening solutions are generally made use of—balsam and benzol, or a solution of shellac in alcohol. The latter is much the better of the two. The solution should be quite limpid. For soft limestones, a soaking of two or three days will be sufficient, but a piece of boiler incrustation will require to be left in the solution for at least a fortnight. When the rock is thoroughly impregnated with the hardening solution, take it out, and put it to dry in a warm place until the solvent has evaporated, leaving the balsam or shellac in the pores quite hard.

Sections of rocks which contain organisms—such as foraminifera—should not be ground very thin, or most of the fossils will be ground away, leaving the section quite useless as a specimen.

Most thin rock sections photograph better by polarised light, as the structure is thus much better shown. Sedimentary rocks, even white limestones, stop a great deal of light, and will require a long exposure. Such sections are always much improved by a few days' soaking in balsam and benzol, to render them more transparent.*

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* Mr. Cuttell, of Soho Square, is most expert in preparing thin sections of hard rocks. A large assortment of rock sections, ready cut, may be seen at Mr. Russell's, 78, Newgate Street.

CHAPTER XII.

PREPARING CRYSTALLIZATIONS FOR PHOTO-MICROGRAPHY.

Most chemical crystals are mounted in balsam, as they are usually viewed by polarised light; but where this is inapplicable, or when the crystals are soluble in balsam, this medium must not be employed, and the crystals must be simply evaporated from an aqueous or alcoholic solution on a clean glass slide, and covered with a circle of thin glass. The majority of chemical salts are soluble in water, and when typical crystals are not required, the addition of a little gelatine to the water will usually produce larger, and in some cases more beautiful, forms. However, as the genuine typical forms will be generally required in a photograph, it is best to use nothing but distilled water, or pure alcohol, in making up the solutions. To obtain typical crystals, the solutions should not be concentrated, but normal, and the evaporation of the salt should not be accelerated by too much heat. As a general rule, the most perfectly formed crystals are obtained by very slow evaporation in a cool place. Many salts, if evaporated in a hot room, or over a lamp, give nothing but a confused mass of amorphous forms. It is often better, instead of applying heat to a drop of the solution on a glass slide, to make a hot solution in a test-tube, and evaporate a few drops slowly on the glass slip. Arborescent crystals, no-

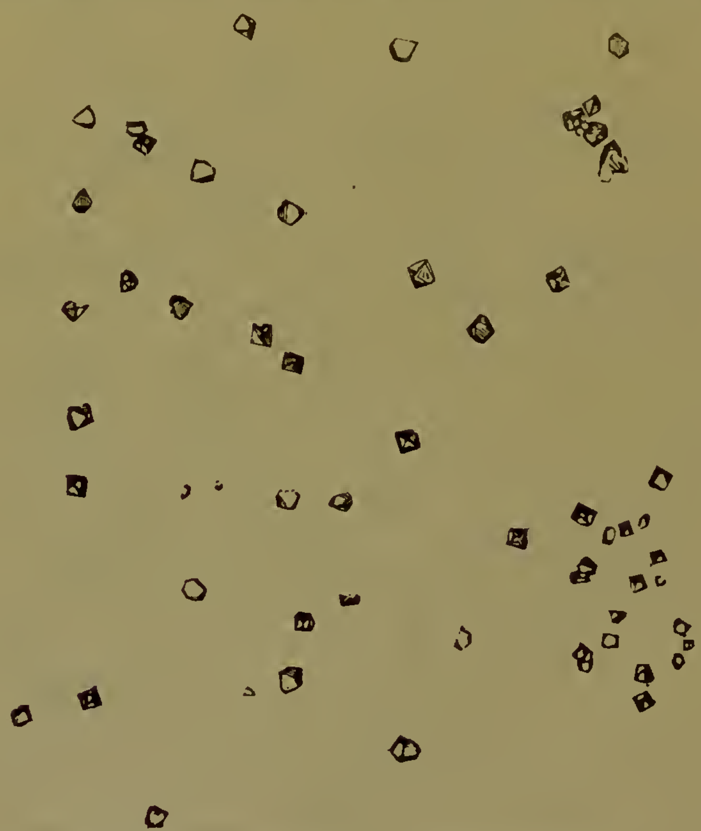
matter how beautiful in themselves, are a great nuisance when the student wishes to prepare the typical forms for photography, and they may be avoided by allowing the solution to crystallize out slowly. Potassium bichromate, if crystallized rapidly, either over the lamp, or from a hot solution, usually gives arborescent forms; but when evaporated in the cold, the character-

CRYSTALS OF ARSENIC, FROM A DEPOSIT OF ·002 GRAIN.

istic prismatic crystals are obtained. All salts crystallized from an alcoholic solution should, as a general rule, be evaporated in the cold. As an example of this, magnesium platino-cyanide,

when evaporated from an alcoholic solution rapidly, gives only an amorphous red mass. To obtain the prismatic crystals arranged in rosettes, the solution must be evaporated slowly in a cool room free from draughts.

White arsenic, As_2O_3, may be obtained either from its aqueous solution, or by sublimation. The latter mode gives more brilliant and regular crystals, but is more troublesome. A small



CRYSTALS OF ARSENIC, FROM A DEPOSIT OF ·001 GRAINS.

portion of arsenic should be put in a short test-tube about one inch long, and a glass slide laid over the top. On applying heat, the crystals will form on the sides of the tube, and on the

slide. By a little careful manipulation with the spirit lamp, the bulk of the crystals may be driven from the sides of the tube, and made to crystallize on the glass slip. They should be covered with a circle of thin glass—no balsam must be used, or they become too transparent to photograph. The accompanying cuts, photographed from slides of ·001 grain, and ·002 grain of arsenic, show the general form of the crystals.

Strychnine is very insoluble in water, so it should be crystallised from its dilute alcoholic solution. The form of the crystals is the octahedron, or square prism—usually the latter. As it dissolves in balsam, it should be mounted dry. With a solution of picric acid strychnine yields hook-like crystals, which may easily be photographed with a low power.

Brucia must be crystallised from alcohol. The crystals are oblique rhombic prisms. It dissolves in balsam rather rapidly, so should be either set up dry, or in castor oil.

Atropine, caffeine, and narcotine crystallize in needles. The former must be mounted dry. Morphia, and morphia chloride, sulphate, and acetate may be crystallized either from water or alcohol, and mounted in balsam.

Quinine sulphate gives a profusion of silky needles from a dilute alcoholic solution. Owing to their delicacy they are difficult to preserve, but may be mounted in dilute balsam and benzole.

Sulphur must be dissolved in carbon bisulphide. The best crystals are obtained in winter; but at all times of the year the solution must be evaporated in a room quite free from draughts, and as cool as possible. These crystals must be photographed by reflected light with a low power. Salicin is a very favourite microscopic object; but the splendid discs usually seen on slides are only modifications of the typical acicular crystals. The real forms are best obtained from a dilute aqueous solution, which may be hot. If a little gelatine be added to the solution, delicate discs form on crystallization, which are seen to consist of needles,

radiating from a common centre. Fusion of the dry salt gives only coarse discs, but if a concentrated aqueous solution be made and evaporated over a lamp until fusion just commences, very delicate discs of a larger size may be obtained. One method of obtaining fine discs is to put a solution of salicin in gelatine on a glass slip. Warm the slip over the lamp for a few moments, and then pour the solution off; enough will be left on the slide to form a thin film. The film is then pricked in several places with a fine needle, and immediately crystallization commences from each prick as a centre, and goes on all over the slide. The whole is at once covered with balsam and benzol, and a thin glass square gently pressed on. If not covered at once, the crystals become opaque.

Santonin and phloridzin are crystallized from an alcoholic solution, and may be preserved in balsam.

CHAPTER XIII.

BACTERIA, AND THE MODE OF PHOTOGRAPHING THEM.

It is intended to devote this chapter to a brief notice of the minute organisms, called by the generic name of Bacteria, micro-organisms or microbes, and the mode of photographing them. Before entering upon the details of this more difficult part of photo-micrography, it is premised that a few general remarks upon the classification and nature of these minute beings may not be without interest to the reader. They are made to take their place at the Sanitary Board, and are largely questioned about sanitary conditions, in which they present themselves under a very suspicious aspect. They have to tell something about the cattle plague, the rouget of pigs, glanders, the fowl cholera, phthisis or tubercular consumption, relapsing fever with its spirillum, quarter evil, erysipelas, scarlet fever, whooping cough, measles, diphtheria, typhoid, pneumonia, leprosy, and various other afflictions flesh is heir to; and now they are stated by some to have a word to say on cholera. The cattle plague, or splenic fever, has been largely investigated by many; and the *anthrax bacillus* is accused, without hesitation, of causing this very fatal disease in cattle, and the "wool-sorter's disease" in man. Fowl cholera has been closely studied by M. Pasteur, who supposes it to be caused by a minute microbe; whilst the *bacillus* of phthisis is amongst the valuable discoveries of Dr. R. Koch, who lately, after serious investigation, also brings forward a "comma-shaped" or curved *bacillus* as the cause of the scourge of cholera, by some believed to be a spirillum. The researches of Dr. Koch, now at the head of the Imperial Sanitary Board of Berlin, command respect, and in the

case of consumption have been by others repeatedly verified; yet the "comma-shaped" *bacillus* of cholera has not been supported by evidence considered absolutely necessary to establish its claim as the cause of cholera. Investigations are still being pursued by others, and no doubt will, ere long, be either confirmatory or negative; until then it is as well to bear in mind Dr. Koch's views, with the fact that a peculiar shaped bacillus has been found in the rice water excreta and in the intestines in cholera, though not in the blood, and that it is generally most abundant in the most serious cases.

These minute organisms are not originators or associates of the diseased conditions of man and animals only, but bacteria are also found in the fatal diseases of some insects, which contribute largely to the comforts of man, as, for example, in "*pebrine*" and "*flacherie*" of the silkworm (bombyx mori), which have been carefully studied by M. Pasteur, and others, and the "foul brood" of bees which has been investigated by Mr. Cheshire and Mr. W. Cheyne.*

The micro-organisms are distributed in the air, in the earth, and in water, and the great difficulty is to find where they are not. In the former they diminish in number according to the purity and the height of the atmosphere from inhabited places, and in some very careful and late experiments conducted by M. Ed. de Freudenreich they were found to be very rare in high altitudes; 2,700 litres of air drawn through or into sterilised tubes in various quantities at heights ranging from 2,000 to 4,000 metres on the Bernese Alps, furnished no bacteria, and later experiments have borne out the extreme purity of mountain air away from habitations; the same experimenter found abundance of microbes in the air of the city of Berne. They are being sought for at sea by M. le Commandant Moreau in his voyages across the Equator, and at certain distances from the coast line, and though very rare, show their presence everywhere; whilst at the Observa-

* *Journ. Roy. Mic. Society*, April, 1885, p. 383.

tory of Montsouris, Paris, they are regularly collected by the use of appropriate apparatus, and statistically noted in special tables by that excellent observer, Dr. P. Miquel, the author of the unique book, "Les Organismes Vivants de l'Atmosphere," published by Gauthier-Villars, Paris, who there gives, as also in the "Annuaire" of the Observatory, the results of his observations on the air of the wards of hospitals, of streets, of the large Parisian Cemetery, of sewers, of the dust of apartments, of earth, &c.; all the results are tabulated and reduced to curves, or stated statistically, or comparatively, with the known meteorological conditions as regards moisture, temperature, barometric pressure, force and direction of wind, and rainfall. The latter curves, and those of epidemics, are often seen to correspond very closely with the fall and rise in the curve of the microbes. Curiously, he has also detected a daily maximum and minimum in their numbers, the cause of which remains to be investigated.* They are found in ice, in hail, in snow, and in rain, as may be expected. They effect decomposition by putrefactive fermentation. They act as the scavengers to the refuse of all higher organisms, and at last determine the ultimate changes of death. They inherit energies of enormous power, so that in whatever light we may view them, they are entitled to the study and attention of the photomicrographer. Thus, they force themselves upon our notice in various zymotic diseases; they are the companions, if not the causes, of many of the diseases common to man and animals; and they break down the structure of the finished life for the rebuilding of new forms. Decay marks their path, whilst their own life history is in many cases a mystery.

From the foregoing it will be seen that some at least are pathogenic, or breeders of disease; others appear harmless in

* Two max. and two min. in the twenty-four hours. A rise between 6 and 8 a.m., and 6 and 9 p.m.; a fall between noon and 2 p.m., and midnight and 3 a.m.

this relation, and are described as non-pathogenic. How far they may, under alterable conditions, be convertible, if at all, as by transmission through the bodies of various animals; or how far in all cases they retain their respective and distinctive characters, never passing from the one to the other in their pure state, remains for continued investigation as a question of deep interest. That they can be altered, or the virulence lessened, has been largely proved by inoculation experiments carried on in France and elsewhere, so that when inoculated into animals they act less virulently, yet render the inoculated animal immune to the strongest similar virus. It is here that they have a very large commercial bearing upon the ratio of consumption and supply, as affecting the lives and preservation of animals necessary for the use of man. Many of these organisms have been long known, and were sometimes placed with the animal, sometimes with the vegetable kingdom. They are now considered as belonging to the latter, and to stand at the lowest confines of life. The vastly superior methods of discovering and distinguishing them, due to the greatly improved defining powers of the microscope, and the distinctive characters conferred by various methods of staining, have made their class legion.

They have been classified in different ways, artificially and provisionally, by different investigators. For the present purpose, and as the most simple, they may be stated as belonging to the Schizomycetes, or fission fungi, fission being their natural mode of increase, though some are known to form spores; these usually resist such influences as speedily destroy life in their ordinary condition. This is not the place to go very much into detail respecting them; hence for the present purpose they may be divided into four heads:

1. *Micrococcus* (*Sphærobacteria*).—The micrococci are minute round or oval bodies varying from less than about the $\frac{1}{25000}$th of an inch to double this size, or more, remaining always microscopic. They elongate slightly, then divide into two and repeat

the same fission; or the two may remain in contact and resemble dumb-bells, or the division be repeated at each end, forming a shorter or longer chain. If the division also occurs in another direction, they take the form of a square, or a cubic form. Many appear under the microscope surrounded by a pale substance of a different refractive power, sometimes soluble in acid or in alkalies, and containing one or more in the same arœola. The morphological appearances of many closely resemble each other, so that they cannot microscopically be distinguished, whilst by culture in fluids or on solids they determine very different effects, showing them to have dissimilar functions. They are said not to possess motion, save it be of the ordinary Brownian character. This is rather doubtful with some. They can determine colour in some fluids; the red colour by micrococcus prodigiosus, a scarlet by micrococcus indicus, &c.; also orange and violet colours. Some are found in milk, but are apparently harmless. Others are found in the acute stage of pneumonia, and these, when stained, show a beautiful arœola. Others are found in erysipelas and in small-pox, &c.; they are occasionally found in the sarcina form, or squares of four.

2. *Bacterium* (*Microbacteria*).—The bacteria proper differ from the foregoing, though they sometimes so closely resemble those in pairs, that it is almost impossible to correctly distinguish them. They consist of elongated and oval, or cylindrical short rods that divide by constriction and fission, and generally remain in pairs; most of them are endowed with motion; some move with great rapidity, and possess a flagellum, lash, or cilium at one or both ends; possibly all the motile forms possess them. The ends are generally rather sharply rounded. Some are very minute, and are endowed with powerful pathogenic properties in the smallest quantities, others in fairly large quantities, or not at all. They are readily found in decomposing animal or vegetable infusions, giving the odour of putridity and staleness, also determining colour in some cases. They may

change the material in which they originate, or live, and render it virulent apart from themselves. They mostly prefer neutral or slightly alkaline media, though some multiply rapidly in acid liquids, as in acetous fermentation; others will multiply readily in a purely mineral or inorganic saline medium, as Cohn's fluid. They sometimes form long chains, often in zooglœa masses on the surface of the fluid; some are photometric. The rapidity of their growth in suitable media and temperature is simply marvellous, and this to such an extent that they often supplant, to total exclusion, other forms. The common form is that of bacterium termo less than 1μ micromilletre, or $\frac{1}{25000}$ of an inch, in length. Some stain more readily than others.

3. *Bacillus* (*Desmobacteria*).—The bacilli are also small, narrow rod-like bodies, that always divide across the short diameter, or contrary to the line of growth. They are of very variable sizes, from the minute form less than 1μ in length, found in the septicœmia of mice, to that of bacillus ulna, 0·01 mm. Some are with difficulty distinguishable from bacteria. They are of very variable length; some divide and separate very rapidly, or form long narrow threads, simple, or intertwining like a mass of hair, according to the medium, temperature, or mode of culture, &c., eventually becoming partitioned into portions of different lengths, and in these the plasm may become so differentiated as to form one spore in the short, and more than one in the longer rods, if the conditions be favourable for spore formation; the wall of the rod playing the part of a sheath, eventually breaking down and liberating the spore. The spores are mostly round or oval, bright, refringent bodies, possessing great tenacity of life, or resistance to agents readily destructive to the rods, supporting a temperature far above the boiling point of water, and much below that of zero. Some are motile, but all are supposed to possess a period of rest. One of the largest and most typical is the non-motile bacillus of anthrax, splenic fever in cattle, and "woolsorters' disease" in man. The rods are always present in

the blood in such cases, and in many of the organs, especially the spleen. Its spores have not been found in the living animal, but the rapid growth of the rod suffices to destroy life very speedily. The bacillus of hay is easily obtained by steeping a little hay in freshly-boiled distilled water, a scum forming readily on the surface at suitable temperatures. The rods are motile, and closely resemble the anthrax bacillus, but are smaller. The spores are often seen at the end of the rod, or in its middle. This is innocuous as far as experiments have gone, although it has been asserted that it can be made to pass into the anthrax variety, and *vice versa*. This statement needs further proof, for the difficulties that surround such evidence are almost beyond the control of the most able and cautious experimenter. Some bacilli are the torment of the brewer if found amongst the sowing yeast; many are often found in the sediment of bottled beer, to which beverage they communicate an unpleasant taste and odour. The bacillus of anthrax has been attenuated in various ways, so as to give to the inoculated animal a mild form of disease, and render it safe against the most virulent virus. The virulence of the bacillus found in the "rouget" of pigs is attenuated by passing it through the body of the rabbit, but augmented if passed through the body of the pigeon. That of anthrax has been found in cultures of the milk of lactation in animals dead of charbon, and capable of infecting similar animals.

Various forms are found in the earth, and Dr. Miquel estimates 700,000 organisms as existing in one gramme at the depth of 0·20 of a metre from the surface in the soil at Montsouris.

The bacillus of turbercle is in little chain rods, straight, curved, or angular. They are found easily in the sputum of phthisical cases by compressing a small quantity of the greyish nodular sputum, between two thin clean cover-glasses, to a thin even layer, then separating the glasses by sliding them one from the other, and drying them; then holding the cover at the edge by forceps, it is passed through the flame of a spirit lamp three or

four times, and afterwards stained according to the plan devised by different pathologists, as stated in the various text-books,* Erhlich's, Weigert's, or Gibbes' plan being very effectual, and by which these bacilli only retain the stain; they can then be easily seen by a $\frac{1}{8}$th. They have been very largely experimented with upon animals to the entire confirmation of Dr. Koch's statement, both in this country, and by Dr. G. M. Sternberg, in America.

4. *Spirillum (Spirobacteria).*—The spirilla are short or long curved rods, taking the simple form of the letter S, as that of the so-called Vibrio, or that of a corkscrew with very many turns; in one instance, thirty-eight were counted to one rod. The turns may be more or less sharp and abrupt, as in Spirillum undula, or more open and flowing, as in S. volutans. Some are amongst the largest of the bacteria, and are provided with a cilium at each end. Some progress in a wandering way, others by a rapid rolling motion. Some are rigid, and others flexible, as Spirochœta. Different names have been given them according to the greater or less possession of the above characters, as Vibrio, Spirochœta, Lepothrix, the latter being found with very many other bacteria in the collection of tartar about the back teeth. The "comma" shaped bacillus found in the rice-water evacuations, also in the cavity of the intestines of cholera patients, in some cultivations outside the body, occasionally takes a more or less perfect screw shape, and is by some considered to belong to Spirillum. It is stated to be present in the mouths of healthy individuals by Dr. Timothy Lewis. Bacteria of various forms are said to have been found on metal and paper money in circulation, also on the human skin.

Passing, for a moment, to other minute organisms likely to be often found with the bacteria, may be mentioned the Saccharomycetes, the yeast fungi, cultivated for brewing, and other purposes, and the natural yeast ferments, found plentifully on the stems and outside of fruits. They occur as delicate cells,

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* "Microtomists' Vade Mecum," by A. B. Lee. 8vo, 1885, London.

with a watery interior and minute granules. They grow by budding, the buds forming a single chain, or an irregular star shape. Of the Zygomycetes, the mucors are in abundance in the air and other situations; some are capable of acting as ferments; they possess a more perfect structure than the foregoing, and a different mode of growth, though, singly, they may have a close resemblance to some of the cellular forms. Among the Hyphomycetes the penicillia take their place; these abound everywhere, and when forming their conidia are most beautiful microscopic objects. They are a class of common moulds, among which is the green mould of cheese, Aspergillus glaucus, &c., so the student must be prepared to meet with numerous small organisms that pass under the common names of rust, smut, mildew, a class of parasitic fungi on animals and plants, often inducing the death of the host. Amongst these is abundant material for study and educational purposes if reproduced photographically.

Staining Agents, and Mode of Staining.—To return to the bacteria, these minute microbes require some means to be used for rendering their presence more visible under the microscope than when seen in their natural state, and to distinguish them from minute inorganic particles or amongst diseased or healthy tissues; hence some process of staining is generally adopted, and by preference the various aniline dyes are employed. To the pathologist and histologist the blue colours are most valuable, as easily differentiating these organisms. They easily take the stain of methyl violet, gentian violet, methyl blue, aniline brown, chrysoidin, magenta, rose-aniline, &c.; also of osmic acid, iodine in iodide of potassium, or tincture of iodine, and sundry other stains. Unfortunately, it so happens that those most generally useful to the pathologist are those most unfit for photography. The various blues and violets allow the actinic rays to pass readily, consequently the negative does not present the contrast required, and the objects

do not appear well defined, being more or less of the same tint as the field, and they do not yield such satisfactory prints as when stained by suitable dyes. Lately, however, it has been stated by M. Dufrenne that he has found no difficulty in photographing objects stained with fuschin or magenta, when he used a green glass, of a complementary colour, between the back of the objective and the sensitized plate. Although the materials are at hand, time has not allowed of testing the value of this proceeding. It may be mentioned that coloured media, as glass, gelatine films, coloured varnishes, have been used years since for improving the ocular image, and, in some cases, photographically. It is not enough to obtain a single black image of the object; what is needed is to try and secure some of the very delicate details many of the organisms possess, as rotundity, granularity, cell wall; and it must be remembered the appearance of the object is greatly altered when focussed on or into many of these microbes, in the former case appearing as bright, beautifully refracting bodies, and in the latter as grey and less refringent. In the yeast cell, at its early and vigorous stage, the transparency and tenuity of the cell, with its watery plasm, is very marked; but by age the cell wall becomes thickened and dense, the plasm coarsely granular, and the vacuoles appear larger or more numerous. These and such-like organisms, as mucor, penicillium, aspergillus, do not require to be stained unless for special purposes, and they can be mounted in distilled water, in weak or saturated solution of potassic acetate, or glycerine and water, only it must be borne in mind that injurious osmosis is likely to occur when the density of the liquid is too great, or has any special action on the contents of the cell.

It would be quite out of place here to record all the methods of staining; one plan will be mentioned, which will serve as a guide. A strong solution of roseaniline acetate, or Bismarck brown of the best quality, preferably of German make, being

prepared with distilled water, boiled and filtered, a small quantity of the fluid medium containing the bacteria is taken up by a fine glass rod, or platinum wire bent into a small ring, and placed on a clean thin cover glass, and made to occupy the greater part of its surface. The cover is taken up by forceps, and set resting with its lower edge on clean blotting-paper, or a pointed strip of the same is made to drain away the surplus, if any. When dry, the cover is, sometimes, also passed rapidly through the flame of a spirit lamp to further fix the organisms to the surface, to be ready for staining when cold, which may be done by dropping the cover, face down, on a little of the stain filtered into a watch glass, and allowing it to float on its surface, or by dropping upon the cover itself sufficient of the stain to completely cover the objects, and covering the same with a large watch glass to protect from dust. If the former plan be used, the stain, when finished with, may be generally discarded as contaminated; the time allowed for the stain to act may vary from a few minutes to one or several hours. In either case the stain is washed off with distilled water from the wash bottle, or the cover is placed in successive small saucers of distilled water, to get rid of the superfluous stain. Sometimes it is flooded with half per cent. to one per cent. of acetic acid, and washed with distilled water; sometimes with absolute alcohol if over-stained; it is then dried by resting on blotting-paper as before. After becoming dry, it is well to examine the objects by placing the cover on a slide, film upwards, and looking at it through the microscope before cementing it to the slide, or mounting it in Canada balsam or any suitable fluid medium. It will often be found the organisms are lying much too closely together, or that some soluble substance that was contained in the original fluid, and has been dried on the cover, has been partially stained, or has rendered the field finely granular; or the organisms have run together into close networks; or some other faults render the object useless for the pur-

pose desired. Diluting the original fluid by distilled water will often get rid of much of the soluble substance, or by pouring off some of the original fluid, then adding water, and allowing the bacteria to subside before removing some to the cover glass. The prevention of the organisms running together is in some cases very difficult; fewer should be placed in a droplet of distilled water on the cover. Sometimes the dried specimen can be laid down upon a clean slide, and a drop of the staining fluid placed at one side, and allowed to run in. After due time, a pointed strip of blotting-paper may be placed at the opposite edge, to withdraw the staining fluid, at the same time that a little distilled water is allowed to take its place; the slide should now be examined. This may be repeated several times, and when sufficiently washed, placed over a watch glass and allowed to dry in that position. In this way the liability to run into lines may be lessened. If found upon examination to be satisfactory, it is perfectly dried, and fluid Canada balsam allowed to run in beneath the cover; or with care the cover can be cemented with Hollis' glue, and preserved as a dry mount. Generally, too much stain remains upon the slide, and many of the organisms have fallen upon it, so that they could not be in focus at the same time with those on the cover; hence it is best to lift the cover, clean the slide, and perhaps the cover itself may need further washing and perfect drying, before putting a drop of balsam on the slide, warming it gently, and placing the cover upon it to complete the mounting. It is as well, if the slide is likely to be used with an oil immersion lens, to run round the edge of the cover a little of Hollis' liquid glue or other cement insoluble in the cedar oil. Some of the bacteria stain very readily, others more slowly or with difficulty, and if measurements have to be made, they will often be found to have considerably altered by the drying, staining, and mounting process when compared with those mounted direct from the original liquid, or in distilled water. Some dry very perfectly on the cover glass, and can be

photographed in this condition without further mounting. The staining material may also be dissolved in glycerine (after the plan so largely used by Dr. Beale in his histological researches), then washed with glycerine slightly acidified with acetic acid, and mounted in the same medium; or some of the staining material may be used neutral, slightly alkaline, or acid. A few are found to fade after being mounted.

The bacilli—except the tubercle bacillus—and the spirilla are generally more easy of preparation. They are less likely to be too crowded or to run together. The hay bacillus stains very nicely with Bismarck brown; also with roseaniline and acetate. Whichever plan may be adopted, it is well to examine the slide carefully for the best part for photographing, as in places some of the organisms may be found to lie on the slide; whilst only those on the cover should be imaged. The examination should be made with a high power—after selection by a lower power—as the 1-8th. The bacillus of tubercle requires a special method of staining to distinguish it from other bacilli that often accompany it. It is also as well to obtain one specimen of the organisms by methyl violet by way of comparison; if this aniline dye be not at hand, a bottle of the ordinary violet ink may supply its place. Osmic acid appears to contract the body of the organism more than iodine in iodide of potassium, or even tincture of iodine; in the two latter, the stain is paler than with the Bismarck brown.

Method of Photographing.—Supposing the preparation to be satisfactory, it remains now to point out a method to secure a fair negative, for the accomplishment of which the best optical appliances, inclusive of a perfectly steady stand, are to be strongly recommended. Assuming these to be at hand, and artificial illumination with the rapid gelatino-bromide plates to be used, before fixing the slide on the stage at the part selected, centre the sub-stage achromatic condenser carefully, then fix the slide on the stage, and regulate the position of the condenser by its rackwork,

until, if using daylight for the examination, the brightest image is obtained by central illumination, the field all over being equally bright. Test the object with the highest eye-piece the objective will bear, and cut down all surplus light by the substage diaphragm wheel, thus obtaining the best possible image. Having carefully turned aside or removed the mirror and the eye-piece, attach the instrument to the camera in such a way as to be light-tight at the junction; place the lamp, a large 1-inch or $1\frac{1}{2}$-inch single-wick paraffin lamp, as close up to the stage as convenient, the flame being turned edgewise to the object, and in a truly central line with the objective; now place the bull's-eye with the flat surface near to the flame, or so as to fill the back lens of the condenser with parallel or slightly-converging rays. Close up the camera (if of the expanding form, as perhaps the most convenient) upon the body tube, cover all the apparatus up to the stage with the camera cloth, and focus the object by a Ramsden eye-piece upon the ground glass; then carefully draw out the camera, keeping the image constantly in focus as the magnification proceeds. Determine the point at which this is to be arrested; now examine for some particular part in the focus previously fixed upon, as affording the best general or particular image, decide whether the focus shall be on or into the object, and fix the camera firmly on its stand. Now wait for at least five minutes, then re-examine the image on the screen; it will most likely be out of focus from expansion by the heat from the lamp; re-arrange the focus, and again wait a little time. When all remains stationary, insert the sensitive plate holder, cut off the light to the sub-stage condenser by a card made to rest against it, withdraw the shutter very carefully, wait a few seconds, then snatch the card away, and give the necessary exposure (say, five to ten minutes) according to power of the light, objective, length of camera, and sensitiveness of the plate used. Develop by any of the formulæ recommended with the make of plate, or one that gives as little granularity as possible; the

pyro, soda, and sodic sulphite developer is generally useful; with high power and lamp light it is seldom possible to get a very dense field without over-developing the image, and from the organisms being so small, it is useless to apply the same means for the observance of the image in process of formation, as in landscape or portrait photography; in this lies much of the difficulty attendant on this part of photo-micrography.

This is one of the simplest arrangements and within the usual reach of the microscopist, but it has been found that certain additions and precautions tend to improve the results. A cell with parallel sides containing a solution of alum placed between the bull's-eye and sub-stage condenser will cut off the heat rays. An ammonia sulphate of copper solution in the same situation will furnish a chemical focus, though this is seldom needed with the high powers, and a polished silvered reflector placed behind the flame so as to converge the diverging rays to a circle equivalent to the posterior surface of the condensing lens, if of some size, will increase the brightness of the field. Again placing on the stage a dull-blackened thin brass slide centrally pierced with a smooth bevelled aperture of about one-twelfth to one-tenth of an inch diameter, upon which the object slide is laid, the part to be photographed being over the aperture, and also a large thin metal diaphragm with an aperture nearly the size of the bull's-eye condenser placed between it and the lamp, so as to prevent the passage of reflected light reaching the objective, will often conduce to the purity of the image. A pierced metal chimney with a shoulder, upon which the bull's-eye condenser can be centrally fixed, is very useful, but when the light is thus shut up, there is a difficulty in seeing the condition of the flame, unless there be a counter opening with a glass shutter which can be easily closed. There are several special lamps provided for microscopists, very suitable for this work, but would be much more so if the flame were more powerful, only they are rather costly. Some of the paraffin oils are so impure that they quickly

give a brownish, very non-actinic deposit upon the inside of the lamp-glass, and this will require constant removal. The best crystal oil should be used, and the addition of a little camphor, about half an ounce to the pint, may be dissolved in the paraffin oil. It appears to slightly increase the illuminating power. The wick, before being put into the lamp, should be thoroughly dried and most evenly trimmed; and when lighted and turned up to its proper height, there should be no flicker of the flame. If time can be spared to centre the image of the flame given by a large angle sub-stage condenser by direct light, *i.e.*, without the mirror, and this again imaged by a high power objective, and then racked a little out of focus, the field will, by patient management, be found beautifully illuminated, though it may be not quite equal all over. Various forms of condensers have been tried, but of late preference has been given to the use of a Kellner's eye-piece as the condenser; the usual cap with a pin-hole being removed, a single lens about 1-12th inch radius centred on a movable diaphragm is substituted, and made to slide by friction in the ordinary cap to the eye-piece, the position of the small lens in relation to the eye lens being selected that furnished the best illumination. When this is inserted in the sub-stage, and the lamp with bull's eye duly centred with it, on looking at the back or field lens a beautiful circle of light, equally divided by a central rod of light, the image of the flame, is seen if the centring be perfect. The focussing is best done by a rod rotating beneath the base-board of the camera, or at its side, furnished with a pulley, over which is passed a narrow silk braid band, to gear in a groove in the head of the fine adjustment. This is easily thrown in and out of gear if the pulley on the rod be wide, and only slightly raised at its edges. The rod should be capable of being rotated at any part of its length, and be out of the way of accident. Avoid an elastic band or catgut, as this is affected by the atmospheric conditions more than silk. If only a very small negative be required, a little compact

camera slide is made so as to be adapted to the eye end of the body tube, and the low power ocular so arranged by additional tubing, that the images when in focus shall lie exactly in the plane of the sensitive surface when *in situ;* the position of the eye-piece once determined, the parts are fixed by a set screw; then by finding the focus with that ocular, and substituting the prepared plate, the use of the ground glass is avoided.

There have been several devices for this purpose, and most beautiful results obtained, as shown in the very small negatives that were placed by Dr. Roux on M. Pasteur's table at the Health Exhibition, but soon, unfortunately, missing. With such an arrangement the body tube can be lengthened, so as to increase the magnification, as has been done by Dr. Maddox; or a small camera can be attached by a clamp and strut to the stand of the microscope, as figured by Dr. Mercer, U.S., in the *Journal of the Royal Microscopical Society* for August, 1884. In all cases it seems preferable that the camera should not be a fixture to the body tube. If the inclined microscope be placed on a sufficiently long base-board, the camera could be easily supported by a couple of slotted struts with binding screws at each side, rising from the base-board, and the attachment to the body tube made light-tight by a flexible material. The ground glass is a rather imperfect material for focussing the image of bacteria upon; to increase its utility, oiling, or partially polishing part of its surface has been proposed; some attach thin glass covers by Canada balsam to different parts of its surface, or varnish the central portion, or use plate glass unground, or with a collodio-albumenized surface, or a layer of gutta-percha dissolved in chloroform, or a chilled thin varnish. The best thing is a polished opaque white surface to focus upon if the camera can be so arranged. Some have entirely rejected the use of the gelatino-bromide plate, and artificial light, for sunlight, heliostat, and wet collodion plates. The oxy-hydrogen lime light has advantages as regards illumination, and the new oxy-hydrogen microscope by Messrs. Swift

and Son, figured in the *Journal of the Royal Microscopical Society* for Oct., 1884, seems likely to fulfil every necessary want, and to be readily adaptable to photo-micrography.* Water immersion and homogenous immersion lenses of high optical excellence are better than the dry objective. Perfect centring of all the parts is essential, and if increased magnification be required, it can be attempted either with a low power E. P. *in situ*, or by means of an amplifier screwed into the lower end of the draw tube, but a reduction in the sharpness of the image may be expected. When using high-angle lenses, perfect definition scarcely covers more than the central half of the plate. The magnification is best kept within the range between 500 and 1,000 diameters, and if sections of tissues with the bacteria in position are to be photographed, something must be sacrificed to obtain the best definition of these minute bodies. This chapter might be largely extended, but this brief summary of many of the leading points connected with the bacteria, and mode of photographing them, must suffice. An extended bibliography of the subject relating to these microbes will be found in Dr. Sternberg's translation of Magnin's Bacteria. The student must not be surprised if he meet with more failures in this than in any other branch of photography; and he will often have to draw largely upon patience to arrive at success.

Much has been omitted in reference to the bacteria, as their necessity for free air, "aerobic," or, independence of free oxygen, "anaerobic," the methods and materials of cultivation—these and kindred particulars will be found in Dr. Klein's excellent manual, "Micro-Organisms and Disease," published by Macmillan and Co., second edition; and Mr. W. Cheyne's papers in the *Brit. Med. Journ.*, April 25th, May 2nd, &c., 1885; and in "Photo-Micrographs, and How to Make Them," 8vo, G. M. Sternberg, M.D., U.S.A., Osgood and Co., Boston, 1883.

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* See, also, several papers on the Use of the Incandescent Electric Light, published lately in the same journal.

CHAPTER XIV.

DETECTION OF ARSENIC IN FABRICS, AND PHOTOGRAPHING DEPOSITS OF ARSENOUS ACID.

During the past few years public attention has been called to the fact that arsenic is largely used in colours applied to wall-papers, dress fabrics, and other things in daily use. It has been proved by the investigations of several eminent chemists and physicians, that the use of wall-papers or fabrics in which arsenic is present, is attended with danger to health, or even to life. Arsenic inhaled by the lungs, either in the form of powder, or arsenuretted hydrogen, is far more poisonous than when taken directly into the stomach; thus all materials in which arsenic is used should be avoided. It is not intended to enter into the arsenic question here; all who desire fuller information on this most important subject should read Mr. Carr's "Our Domestic Poisons," or his lecture on the same subject, delivered at the International Health Exhibition. Our object here is merely to show how the photo-micrographer may easily test a fabric for arsenic, and by comparison with standard slides of crystals of arsenious acid, be able to estimate pretty correctly the quantity present.

In the report of the National Health Society, the committee on arsenic in domestic fabrics state :—An examination of a very large number of papers supplied by these manufacturers—that

is, certain manufacturers who had abjured the use of arsenical colours—leads to the conclusion that an allowance of half-a-grain of arsenic per "piece of paper"—a piece being twelve yards in length and twenty-one inches wide—would be ample for accidental and unavoidable contamination; and this quantity it is considered would not be injurious to health. It is found that a suitable size for a sample to be tested is 16 square inches, to be cut from one part, or, if thought well, from several parts of the pattern, so as to include the more arsenical colours. The proposed limit of half-a-grain per piece gives ·001 grain per sample of 16 square inches. For ordinary uniform materials, a square of 4 inches by 4 inches may, therefore, be taken as the portion to be tested.

In applying the microscopic and photographic tests to arsenical deposits, it is necessary to have standard microscopical slides with definite deposits of ·001 grain, ·002 grain, ·003 grain, &c., with which the results of an analysis may be compared. Mr. Charles Heisch, F.C.S., gives the following directions for making a standard solution, from which such slides can easily be prepared:—

Weigh accurately 1 grain of finely-powdered white arsenic; put it into a flask and pour on it about 20 drops of strong hydrochloric acid; let it stand for a short time, then add 3,000 grains distilled water, and boil till quite dissolved. When cold, make up the bulk to 10,000 grains. Every measure of 10 grains is then equal to ·001 grain of arsenic.

By evaporating 10 grains, or 20 grains of the above solution on a slip of glass, a deposit of either ·001 grain or ·002 grain of arsenic may be obtained.

Under a magnifying power of 250 diameters, the difference between the two deposits is clearly marked. Taking up slides at random, and placing them on the stage of the microscope, after a little practice, one cannot mistake the ·001 grain deposits for the ·002 grain deposits. On the ·002 grain slides the crystals

are either much larger than the crystals on the ·001 slides, and more numerous; or, if the deposit of ·002 grain is a fine one, the crystals are crowded together thickly in a circle, presenting a strongly marked contrast to any of the ·001 grain deposits, in which the crystals are but sparsely distributed.

If a photograph of the whole area of deposit be required, care should be taken, in making the preparation, that all the crystals are within a circle, and small enough to be taken in by a 2-inch lens. A good 2-inch, with *very flat* field, is necessary, or the crystals at the margin of the circle will be out of focus. A lens of this focus will show the crystals only like small points, but a lens that gives really good, sharp definition, will show the form of many of the larger crystals very clearly. Photographs taken with such a low power, although small, are useful for comparison; but photographs of a portion of the deposit, taken with a good $\frac{1}{4}$-in. or $\frac{1}{6}$-in., are far more valuable, and show the octahedral form of every crystal very distinctly.

In photographing such standard slides with a power of 200 to 250 diameters, a portion of each slide should be taken that shows the best average distribution of the crystals. The light from the lamp will probably be found to be too powerful; it will, therefore, require to be modified. This may be done in various ways: one is to place a piece of oiled paper beneath the slide, to soften the light; another is to use a piece of very fine ground glass, or better still, pale blue glass, either in the sub-stage or beneath the slide; or, if a very powerful lamp be employed, a diaphragm above the objective will give good results. The writer has used the Davis aperture shutter when photographing slides of arsenious acid, and found it more convenient than any other mode of subduing the light. If the lens be used to give an amplification of 400 to 500 diameters, or if a $\frac{1}{8}$-in. be used, perhaps the light will require little or no modification. Ross's diffusion condenser is a very useful piece of apparatus, when concentrated light is not required.

The time of exposure must be ascertained by actual trial, as exposures vary very much, not only with different lenses and lamps, but with different samples of oil. With such transparent objects as crystals of arsenious acid, a very short exposure should be given, or the negative will be flat and hazy. A practised worker will guess tolerably exactly the right time for each object, but a novice had better take a few trial negatives, giving different exposures to each, until the right exposure is found. For developing the negatives, the potash developer will be found most suitable, as with it a very short exposure can be given, while the negatives can easily be brought up to any required density.

For the following concise and practical notes on the testing for arsenic in wall papers and fabrics, the writer is indebted to the kindness of Mr. Henry Carr, C.E., the author of "Our Domestic Poisons":—

Mode of Testing by Reinsch's Process.—From the paper to be tested, cut a piece 4 in. by 4 in., or 16 in. area; all colours must be included, or, if any particular colour be suspected, cut out this colour in sufficient quantity to cover the same area; let the portion to be tested be cut up into small pieces. Place the test tube in the ring support, insert the paper, add dilute hydrochloric acid (one of acid to four of water), half filling the tube, light the spirit lamp with a moderate flame, and place it underneath the test tube.

Take a piece of copper foil 1 in. by ½ in., brighten it with a piece of emery or glass paper, pass a fine platinum wire through a small hole in the copper foil, and as soon as the contents of the test tube boil, insert the copper, noting the exact time, and lowering the flame of the lamp so as to maintain a gentle simmering only. By means of the platinum wire, the copper can be drawn out and examined from time to time as the test proceeds.

If there be much arsenic present, the copper will be coated

almost immediately of a *black* or *dark steel* colour; if less arsenic be present, a longer time will be required, varying from half a minute to half an hour, half an hour being the limit of time for boiling; if in that time the copper be not coated all over of a lamp black or dark steel colour, the paper may be accepted, the cases being very rare in which this process does not detect the arsenic. If the copper be coated all over, the paper is in all probability arsenical, though the process carried thus far does not *prove* the presence of arsenic, for this coating may arise from sulphur, mercury, or some few other ingredients which may be present in the colouring matter. The completion of the test is as follows:—Well wash the copper by shaking it in clean water, holding it by the wire or by a small pair of pliers—the copper must never be touched by the hand; dry it first between two pieces of blotting paper, finally by laying it on a strip of thin sheet brass and warming it over the flame of the lamp—direct exposure of the copper to the flame must be avoided. Take a reduction tube, about 3 in. in length and $\frac{1}{4}$ in. in diameter, dry it by holding the closed end in the flame till nearly red-hot, then slowly pass it forward till the whole is thoroughly heated; taking the copper in the pliers, cut it up with a pair of scissors into such pieces as will pass into the tube; the mouth of the tube should then be closed slightly with cotton wool. Now hold the closed end of the tube containing the copper over the flame of the spirit lamp, gradually increasing the heat; arsenic, if present, will be driven off the copper by the heat, and will be deposited a short distance beyond in the form of octahedral crystals of arsenious acid, which may be examined by a small magnifying glass or under a microscope; if the sublimate consists of octahedral crystals, the discolouration of the copper is due to arsenic. Or the crystals may be sublimed on to a microscopic slide in the following manner:—

Take a thin glass tube, $\frac{1}{4}$-inch internal diameter, and $1\frac{3}{8}$ inches long, sealed at one end and lipped out like a test tube at

the other. Suspend this by dropping it through a hole cut in a piece of stout sheet brass or copper, not less than 4 by 1 inches, so that the lip just supports the tube, and place the brass or copper plate on the ring of a retort stand. Heat the tube nearly to redness, and expel the last trace of moisture, and when cold, put the copper strips within, and place over it, resting on the mouth of the tube, a microscopic slide, warmed in a spirit lamp till all the moisture at first deposited has disappeared. Now heat the tube in the spirit lamp, letting the flame play on the under side of the brass plate. In a few seconds a sublimate will appear on the slide; watch this until it begins to shrink from the edges, and form a patch just the size of the bore of the tube. Remove the lamp, allow the slide to cool, and examine the sublimate with a magnifying power of 220 diameters.

The copper and acid when first obtained must be tested by boiling alone for an hour; if the copper then becomes coated at all, either the copper or the acid is not pure, and must be rejected.

As it is absolutely necessary to employ really pure materials in testing for arsenic, it is well to know where such may be obtained. Messrs. Townson and Mercer, 89, Bishopsgate Street Within, London, E.C., supply the following materials for applying Reinsch's Test, at a cost of 8s. 6d.:—8 ounces hydrochloric acid, guaranteed pure; ½ ounce electric copper foil cut into pieces 1 inch by ½ inch; 8-inch thin platinum wire; spirit lamp; two test tubes of thin glass, holding about three ounces when full; support to carry the test tube; small pair of microscopic pliers; twenty-five thin glass tubes, closed at one end, 3 inches in length, ¼ inch in diameter; a piece of thinnest sheet brass, 4 inches by 1½ inch; supplied direct or through any druggist.

By comparing the photographs of the deposits obtained from analysis of a piece of wall paper, or any fabric, with the photographs of deposits on the standard slides, a very accurate determination of the amount of arsenical contamination can be made.

CHAPTER XV.

NOTES ON LENSES AND OTHER APPARATUS.

This chapter is written specially for the benefit of students who are either quite unacquainted with microscopical apparatus, or who have but little knowledge of what is suitable to their requirements, and it is hoped that the information here given may be of service to all commencing photo-micrography.

Although in the foregoing pages the writer has advocated the use of wide-angle lenses for photo-micrography, as he is convinced that generally the best results will be obtained by their use, he is aware that lenses of medium angle will be chosen by many, not only on account of their cheapness, but also from a conviction that for ease of working and for mixed work they are preferable to lenses of wider aperture; so in this chapter several lenses of low and medium angle will be described, which the writer has found to give excellent results, both in general microscopic work and also in photo-micrography.

For some years the writer has used lenses of medium angle, in addition to others of higher angle, and has found that good results can be got from their use in photography for all ordinary objects, as long as the lenses are well corrected, and have a flat field. Those hereafter mentioned are familiar to the writer from constant use, and he can therefore strongly recommend them :

other opticians also manufacture similar lenses, but only those named have come under the writer's immediate notice.

There are some persons who advocate the use of cheap French triplets, not only for microscopic work, but also for photo-micrography. Now, although there are some fairly good French triplets to be met with at times, that are capable of giving tolerable results, the writer thinks that those advocating their use can hardly have seen and used the cheap lenses of medium angle introduced of late years by all the best English opticians, with which the very best French triplet cannot for a moment compare. Some of the first lenses that the writer ever used were French triplets, obtained from a good London house. These were evidently *picked lenses*, for the ¼-inch would resolve ***P. angulatum*** fairly, and they were not of the cheapest make, for the one named cost 17s. 6d.; but none of them would bear the 3rd eye-piece, and all were evidently of very low angle, as the amount of light they admitted was very small. Still, for anyone beginning microscopical work, and unable to purchase the costly lenses of the first makers, which were the only English lenses then procurable, they were very suitable. French triplets *can* be purchased as low as 9s. to 10s. each, or even cheaper; but such lenses are useless: they are manufactured in the most haphazard style, and the combinations fitted together almost at random, until the several components are found to match *somehow:* such things are obviously quite unfitted for scientific work, and if a fairly good one be found at times, it is by pure accident. Even in the case of the best triplets, those above ½-inch focus not only define badly, and have a strongly curved field, but admit so little light, from their very small angular aperture, that it is strange anyone could possibly advocate such abominations for any purpose whatever.

In condemning common French lenses, it must be understood that there *are* some excellent lenses of French make. Those of Hartnack have a good reputation, especially among medical

students, and at one time were to be specially recommended, as there were then no lenses in the English market equally good at so low a price. Now, however, all this is changed: the lenses of Hartnack, though good, are not so well finished as modern English lenses of medium angle, have a much shorter working-distance, and are generally of smaller angle, or not so well corrected—hence they will bear neither an English eye-piece, nor one of high power, nor a long draw-tube without suffering great loss of light and definition. Long tubes and deep eye-pieces do not *improve* the definition of any lens, but it is only a good one that will bear a 16-inch tube, or a No. 3 or No. 4 eye-piece, without failing. These helps not only are useful in testing an objective, but also enable one often to resolve an object in which the markings are very fine and very close together; and while a good lens will bear this increase of amplification without the image being distorted or enveloped in pitchy darkness, a bad lens will only define the object worse than ever, and display fully all its bad qualities. Thus the student should test every lens he intends to use, either with a C eye-piece, or a long tube, or both. The good small-angle lenses now made by English opticians will stand this test well. All mentioned below will work very satisfactorily with the C eye-piece, without any marked loss of light or definition.

The lenses of Messrs. Swift have been referred to in the chapter on Microscopical Apparatus. The writer has used lenses from both the first and second series for some years, and has been well satisfied with them. In the second series, the writer has found the lenses of high power far superior to those of lower power; and while he finds the low-angle lenses from $\frac{1}{4}$-inch upwards most excellent, he prefers the lenses of the *first* series for photographic work, as these have a very flat field, and a flat field is of more importance with a low power than with a high one. For if, say, a wood-section be photographed with a 2-in. or 3-in. lens that has not a perfectly flat field, this defect will

make itself felt most painfully in the photograph. If, however, a low-power lens be required for general work,* a perfectly flat field is not an essential, and its absence will not be noticed unless this defect be very pronounced. Mr. Swift's first series of lenses, from 5 inches upwards, are all that can be desired, and the lower powers are so cheap, that the student will find it cost little more, and vastly to his advantage, to purchase *all* his low power lenses from this series. Their definition is good, their angle large, and their flatness of field as perfect as the test of photography will require. The 5-inch is very useful for photographing large sections of wood or minerals, or large insects, and is very rapid in action. The same may be said of the 4-inch, which will be found useful in microscopes which have not a sufficiently large rack to use the 5-inch. The wider angled $\frac{2}{3}$-inch., owing to its large aperture, will bear a good deal of topping down for photography, and its penetration is thus much increased; but if the camera be used much extended, it is best to use it full aperture. Of late, Messrs. Swift have brought out a 1-inch of 40°, which has marvellous defining powers. A photograph of a fly's tongue, taken with this lens, is the sharpest and crispest photo-micrograph the writer has ever seen, and quite bears out what he has advanced concerning the advantages of lenses of high angle. In this photograph there is a brilliance and an evenness of definition such as is rarely seen. The hairs, the false tracheae, and every minute marking, stand out with marvellous sharpness.

The 3-in., 2-in., 1-in., and $\frac{2}{3}$-in. in the second series are most excellent lenses, especially when their low price is considered, and very good photographs can be taken with them, and the writer frequently uses them for this purpose. Mr. Swift used to make a $\frac{4}{10}$ in. in this series. It would resolve a fine *P. angulatum* easily and well, and gave sharp definition under the

* That is, for general microscopic work—not for photography.

3rd eye-piece. This lens is not now catalogued, but would doubtless be made for anyone desiring it. It would be a very useful lens to the photo-micrographer, who frequently wants a power between the $\frac{1}{2}$-in. and $\frac{1}{4}$-in., yet who does not care to pay the high price usually charged for a first-class $\frac{1}{10}$ in. The $\frac{1}{4}$-in., $\frac{1}{5}$-in., $\frac{1}{6}$-in., and $\frac{1}{8}$-in. of this series are perhaps the best of all. The $\frac{1}{5}$-in. and $\frac{1}{6}$-in. the writer finds invaluable, as they will not only resolve diatoms of medium difficulty, but, as they are made with conical fronts, they can be used with ease for exhibiting opaque objects. The $\frac{1}{5}$-in. resolves *Angulatum* with A eye-piece and mirror alone, while the $\frac{1}{6}$-in. will go as far as *S. gemma* on the balsam test plate, using an ordinary condenser. These two lenses, the $\frac{1}{5}$-in. and $\frac{1}{6}$-in., are far superior to any foreign lenses of the same focal length, and have a good "working distance;" besides which, their penetration is so good, that they can be used on objects having a very uneven surface. The $\frac{1}{5}$-in. has been used by the writer frequently for photographing crystals, either with or without the eye-piece.

Mr. Collins, in addition to his best lenses, which are well-known and have a good reputation for general as well as photographic work—Dr. Sternberg having employed some of this series for photo-micrography—also makes a series of lenses of lower angle, several of which, the 1 inch, $\frac{1}{2}$ inch, $\frac{1}{4}$ inch, and $\frac{1}{8}$ inch, have been used by the writer. These are the lenses usually supplied with the "Histological" microscope, unless others are desired. The 1 inch and $\frac{1}{2}$ inch are capable of performing very satisfactory work, but as regards photography, the lenses of the first series are preferable, being of wider angle and having a flatter field. On Möller's Balsam Probe Platte, the $\frac{1}{4}$ inch resolves as far as *P. acuminatum*, but will not resolve the *Angulatum*—unless, perhaps, with a condenser—although it will resolve finely marked English specimens mounted *dry*. Diatoms are, as every microscopist knows, far more difficult of resolution when in balsam than when mounted dry. For photo-

graphy, if possible, dry-mounted specimens should be obtained. The $\frac{1}{8}$ inch is the best lens of the four. It goes easily through the balsam Probe Platte as far as *S. gemma*, No. 13, using only the mirror and A eye-piece; yet its penetration is so good as to give a good sharp image of *Aulacodiscus* from edge to edge, spite of the convex shape of this diatom. Small English *P. angulatum*, dry, are at once resolved into dots, without using very oblique light. This lens is very useful for photographing diatoms of medium difficulty, blood-corpuscles, test-scales, and minute organic or inorganic deposits. In the hands of a practised manipulator, it will do as good work as most dry $\frac{1}{8}$ths, costing double the price. The prices of all these lenses are exceedingly low.

Mr. Baker, of High Holborn, has also introduced an excellent series of low-angle lenses, admirably suited to the wants of the student. They are very cheap, the $\frac{1}{8}$th inch costing only 50s. Mr. Baker makes also a "New Model Histological Microscope," a compact, well-built little stand, costing, with case, £3 10s., very suitable for anyone beginning the study of photo-micrography; although the larger size of this microscope, with full-sized tube and heavier base, costing £5 with case, would probably be more satisfactory. Such stands are far better for photographic work than the foreign microscopes, but if the student have a fancy for a foreign model, he could not do better than obtain the Hartnack stand of Mr. Baker, which, in addition to any advantages possessed by this form, has also the advantage of being of sound English workmanship, which in microscopes, as in most other things, is still far superior to that of the French or the Germans. The "Model Histological" should have rack adjustment to the optical tube if intended to be used for photography.

Mr. Baker is also the English agent for the celebrated lenses of Zeiss, Seibert, Kraft, and Leitz. These lenses have been mentioned before, and the student is strongly advised, if he

need any lenses of high power, to try the productions of these makers. English lenses of high power are very dear, and far beyond the reach of the majority of students; still, they are unrivalled, and all who can afford to purchase them should patronise some of the leading makers. Yet, as few will care to pay twelve, sixteen, or thirty guineas for lenses of $\frac{1}{12}$ inch, $\frac{1}{16}$ inch, and $\frac{1}{25}$ inch focus, the foreign lenses of the makers named above will be found to perform at least nearly as well, and be equal to all the work usually required of them. The writer has used several of these lenses, and can thus recommend them for photo-micrography. Any supplied by Mr. Baker can be relied upon as being really good, serviceable lenses, that will give satisfaction. The immersion lenses of Seibert are somewhat cheaper than those of Zeiss, and the prices of a few are here given:—$\frac{1}{12}$ inch dry, £3; $\frac{1}{16}$ inch imm., £3; $\frac{1}{24}$ inch imm., £6.

Zeiss's $\frac{1}{9}$ inch dry, £3 11s.; $\frac{1}{14}$ inch dry, £4 9s.; $\frac{1}{8}$ inch imm., £4 15s. For others, the student is referred to Mr. Baker's Catalogue, but few will want higher powers than these. For powers below $\frac{1}{12}$ inch the cheap lenses of medium angle, now sold by all the best English opticians, will be found as economical and satisfactory as the foreign ones. Zeiss and Leitz also produce *oil-immersion* lenses, which have far greater resolving power than the water-lenses, but they are all costly. However, Leitz makes an oil-immersion $\frac{1}{12}$ inch, of which many of our best microscopists speak very highly, which costs only £5. For photographing diatoms, or minute organisms, the student will find immersion lenses far superior to dry lenses, and the price of many of the above is so moderate, that few students need be without at least *one* high power.

The Webster condenser of Mr. Collins has been referred to before, but lately this excellent condenser has been vastly improved, and now forms a most efficient piece of apparatus. The old wheel of diaphragms has been replaced by a convenient and

beautiful iris, or contracting diaphragm, and an adjustable shutter, working on a hinge, is employed to carry stops for dark-ground illumination and oblique light, making it most complete; while, at the same time, it is much more compact than the older form. All who require a good condenser should see this new form of the Webster condenser. It is made to fit microscopes either with or without sub-stage. This condenser, and the Popular Condenser of Mr. Swift, answer the ordinary requirements of the photo-micrographer far better than any other form that the writer is acquainted with, are capable of resolving most of the difficult tests, and are exceedingly cheap. The Popular Condenser is, perhaps, preferred by the writer, as it has polarizing prism and selenite films in addition, and on removing the lenses that form the condenser, the same mount may be made to carry a small paraboloid. For those who, like the writer, employ the microscope chiefly in chemical and geological studies, no better form of condenser could be devised, unless it be the more perfect model mentioned in the first chapter. However, either will be a great help, and save a vast amount of time in properly illuminating any object that is being photographed. A great deal *can* be done with mirror and bull's-eye alone, but only those who have tried to photograph a difficult diatom with these simple appliances know how much time, energy, and temper, are wasted in so doing. The practical photo-micrographer cannot be too grateful to the optician whose skill and ingenuity have furnished him with these excellent labour and time-saving appliances at so low a price.

A smaller and simpler condenser is also made by Mr. Swift, at the low price of 25s., that will suit admirably those who cannot conveniently obtain condensers of higher cost. It consists of the usual combinations of achromatic lenses, which furnish quite a flood of light, and has also a stop for dark-ground illumination worked by a small lever at one side. It can be used as a spot-lens with the 2-in., 1-in., and $\frac{1}{2}$-in. objectives by moving the

spot beneath in the centre of the condenser. The spot in the same position is of great use for resolving diatoms, lined structure, or nerve fibre. When great resolving powers are required, the stop must remain in the central position, and the large diaphragm, working in the stage, should have one of its apertures moved across the upper lens of the condenser, until the necessary obliquity of light be obtained. In this way, a 4-10 in. or low-angle $\frac{1}{4}$-in. may easily be made to resolve a difficult diatom, as the writer has repeatedly proved, which, without the condenser, would show nothing but the outline of the frustule. Simple as this form is, the student will find it far more to his advantage to purchase this little piece of apparatus, than be altogether without a condenser. In photo-micrography a condenser, properly managed, frequently brings out structural details, which, without it, would either be but poorly shown, or quite obliterated by a flood of light. It is not only when illuminating objects that require "resolution," but in the great majority of cases, that a good achromatic condenser will be found useful. Abundance of light can be got from a good paraffin lamp and a bull's-eye lens, even when using a $\frac{1}{12}$ inch or a $\frac{1}{16}$ inch for photography; and the achromatic condenser is not required so much to *give* light, as to *modify* light, to suit the different objects photographed.

Since the description of Swift's Wale's microscope was written considerable improvements have been made in the stands, which not only increase their utility for general work, but also for photo-micrography. It is a fact, that there are many large microscopes in the market, of fine workmanship, and replete with expensive mechanical stages and sub-stages, that are far inferior to the smaller Wale's model, figured previously, as regards strength and balance. As shown, the stem of the microscope is not hung on trunnions, as in most microscopes, but moves by means of a sector sliding between the jaws of the tripod base, and this motion is marvellously smooth and steady, while the microscope can be firmly clamped in any position by means of

a large milled-head screw at the side, and remains perfectly steady at any angle of inclination. In the smaller stands, a large diaphragm plate, with one aperture the size of the full opening of the stage, and with several smaller apertures, is fitted in the stage-plate itself, and works immediately beneath the object. This feature has several advantages, especially when using an achromatic condenser, or when resolving difficult diatoms. The larger microscopes made on this model, such as that recently exhibited before the Royal Microscopical Society, and fitted with the newest form of thin mechanical stages, sub-stages, and new patent fine-adjustment, are as perfect in every respect as stands costing more than twice the price, and are of exquisite finish. The semi-circular curve of the arm of the microscope allows the mechanical stage, carrying the milled-heads, to perform a complete rotation in the optic axis. The writer believes this can be done in no other form of microscope, except in the largest and very costly microscope of Powell and Lealand, as the milled heads of the stage strike against the arm of the microscope, and thus prevent complete rotation. Concentrically rotating stages are not only convenient, but so absolutely necessary for bringing out the best effects with polarised and reflected light, that it is strange any good microscopes should ever be made without them. In the larger Wale's model, not only is the stage as thin as can be made, consistent with firmness, but the aperture beneath is of very large size, to allow of using light of the utmost obliquity. The milled-heads give a motion of one inch in each direction; and in the stand used by the writer, the concentric motion is so good that a diatom placed in the centre of a $\frac{1}{8}$-in. remains in the field of view during a complete rotation. In the writer's opinion, the Wale's form of microscope—which is of American design—is destined to become not only very popular, but the recognised form for the best instruments.

Messrs. Ross and Co., in addition to their large and costly microscopes, which have gained a world-wide reputation, owing

to their perfection of workmanship and exquisite beauty of finish, now manufacture cheaper instruments, expressly for students, one of which, called the "Brewer's Microscope," is here figured (fig. 2). As will be seen, it is made on the same model as the larger stands, has a good mechanical stage, but is not

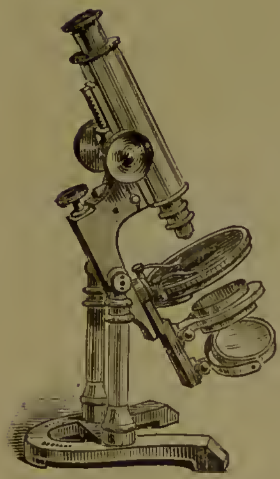

Fig. 1.

Fig. 2.

fitted with sub-stage. For general photo-micrography it would be very suitable, especially if used with Swift's Popular Condenser, or Collins' Webster Condenser. It is hardly necessary to say, that like all the work of Ross and Co., it is well-made and of solid construction. The mirrors, too, are of very large size. Smaller microscopes are also made by this firm, but none of them, excepting their No. 4. stand (fig. 1), which has a sub-stage, are well adapted to the wants of the photo-micrographer.

The latter stand has, however, most unfortunately, eye-pieces of the Continental size—why, it would be hard to say.

Ross and Company also have a series of small-angle lenses, sold at a moderate price. These vary in price, according to their angular aperture, and of these the writer has practically tested a $\frac{1}{10}$ inch and a $\frac{1}{8}$ inch of 110°. Like all the productions of this house, these lenses proved most satisfactory, and will answer fully the purposes of those who have an objection to lenses of high angle. The first series of Messrs. Ross are all that can be desired.

Messrs. R. and J. Beck have several small students' microscopes, such as the "National" and the new form of the "Economic," which would form suitable instruments for practising photo-micrography. The "Popular Microscope" is not fit for this work. In the writer's opinion, a microscope to be used for photography should be on the Jackson model, with firm tripod base, *full-sized* tube, and have a fitting beneath the stage for carrying the *full-sized* condensers and other accessory apparatus. If it is to be used with high powers, a *good* mechanical stage, of large size, and rotating concentrically, should also be applied.

In conclusion, the writer would most earnestly advise the student to buy none but the very best apparatus his purse can afford, and to patronise none but the first opticians for microscopes, lenses, and microscopical appliances, if he desire to do *real work*. It has been shown that good apparatus is not necessarily high-priced, and, besides being capable of doing the best work, will give pleasure every time it is used. The writer insists on this point the more strongly, because he knows that it is the inexperienced, who although most standing in need of good advice, are yet the least disposed to take it, and the most confident in their own judgment, and it is such who usually fall a prey to the puff of the unscrupulous trader, and furnish a market for worthless apparatus. Many of the best microscopes

of our first opticians, of the finest workmanship and finish, are furnished with a *bronzed* foot and arm, simply to enable the maker to sell these instruments at a moderate price; yet the writer has known a wretched, shaky, worthless microscope, fitted with the very worst French lenses, to be preferred, simply because, forsooth, it had a gaudily-lacquered stem and base, and a ricketty mechanical stage! and this, too, when the purchaser had been advised, by experienced microscopists, as to the best instruments to purchase. More especially would the writer caution the novice against buying the £5 and £6 microscopes, supplied with bad French lenses and execrable focussing adjustments, to be obtained from *dealers* both in London and the provinces. Really excellent microscopes, at the same price, and provided with two good English objectives, can be had from most of the makers named above, which are made for real scientific work, and which no scientific man would be ashamed to use. Scientific instruments must always be made by skilled workmen if they are to be of use; and the beginner may depend upon it that the most perfect instruments will be made only by those who have devoted a life-time to the work, and who have a reputation at stake.

NOTE ON R. L. MADDOX'S "BACTERIA."

Dr. Heneage Gibbes' Stain.—No. 1. — Dissolve 3 grm. of pure anilin (anilin oil) in 20 c.cm. of alcohol (sp. gr. 830), put 2 grm. of magenta crystals in a glass mortar, add the mixed spirit and anilin oil, and dissolve thoroughly; then add 20 c.cm. of distilled water gradually, whilst stirring. Preserve in a stoppered phial.

No. 2.—Add 2 parts of distilled water to 1 part of nitric acid.

No. 3.—Prepare a saturated solution of chrysoidin in distilled water, and add a crystal of thymol to make it keep. The sputum that has been dried on the cover, and passed through the flame of the sp. lamp or small Bunsen-burner, being ready, filter a little of No. 1 into a watch glass, place the cover face down on the stain, avoiding air-bubbles, allow it to remain 20 minutes, wash, and dip it into the dilute acid until the colour is removed which happens in a very brief time; wash away the acid, and place the cover face down on a little of the filtered chrysoidin solution for a few minutes, or until stained brown; re-wash with water, finally with absolute alcohol, and, when dry, mount in Canada balsam. The tubercle bacilli will be seen more or less red stained on a brown ground. If methylene blue be used instead of chrysoidin, it will furnish a blue ground. Some heat the No. 1 solution just up to steaming while the cover is floating on it.

All these anilin dyes, as well as pure chemicals and reagents, can be obtained in any quantities from F. E. Becker and Co., 34, Maiden Lane, Covent Garden, London, W.C.

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